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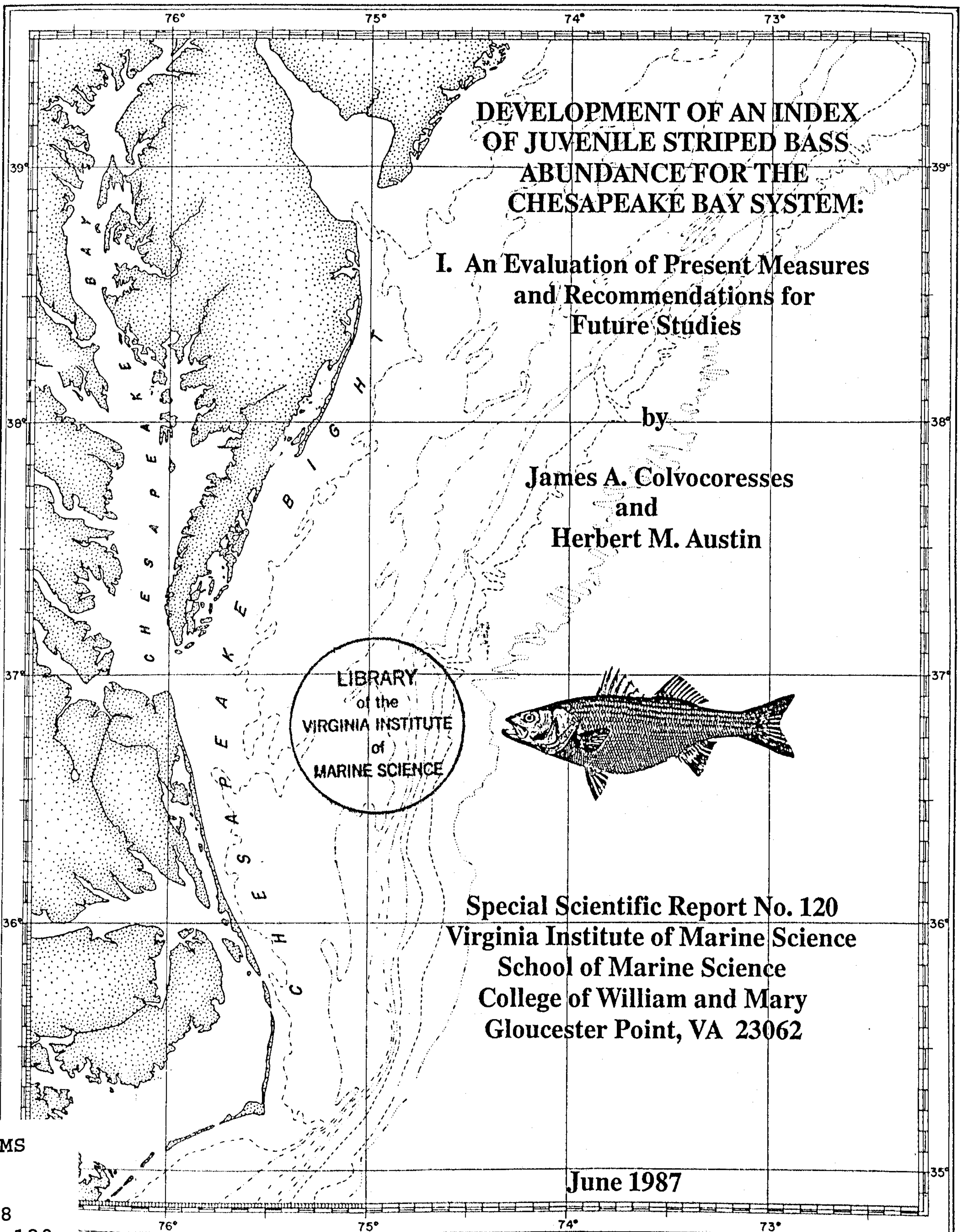

DEVELOPMENT OF AN INDEX OF JUVENILE STRIPED BASS ABUNDANCE FOR THE CHESAPEAKE BAY SYSTEM:

I. An Evaluation of Present Measures and Recommendations for Future Studies

by

James A. Colvocoresses
and
Herbert M. Austin

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Special Scientific Report No. 120
Virginia Institute of Marine Science
School of Marine Science
College of William and Mary
Gloucester Point, VA 23062

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EXECUTIVE SUMMARY

There has been very little coherence between annual striped bass recruitment indices generated by summer beach seine surveys for the upper (Maryland) and lower (Virginia) portions of Chesapeake Bay. Analysis of the potential causes of the differing results of the Maryland and Virginia seine surveys was undertaken as a preliminary step toward the development of a possible standardized Baywide index of juvenile striped bass abundance. The survey data strongly indicate that, with the exception of years such as 1970 (when for undetermined reasons relative recruitment was high Baywide), annual recruitment success is largely independent between drainages, but the observed inconsistencies in the relative annual indices appear to be also largely attributable to high sampling variability.

An alternate index of striped bass abundance was calculated from winter trawl survey data from the Virginia tributaries. Agreement between the trawl and seine indices was poor. Multiple regression of trawl survey indices with subsequent commercial landings produced highly variable results, with no relationship being found in one system (York), but a very strong relationship in another (Rappahannock). The later correlation was largely dependent upon a sharp peak in the juvenile index in 1970 being followed by a peak in landings in 1974.

The influence of dominant environmental variables upon survey results was examined. Salinity evidenced the greatest effect on juvenile striped bass distribution during the summer seine surveys, with similar patterns of distribution being observed in both major portions of the Chesapeake Bay. Distribution of juveniles during the

winter trawl survey period exhibited complex relationships to temperature, salinity and depth which may produce confounded sampling results between years of variable climatic regime.

The seine surveys were originally designed to provide an inexpensive basis for monitoring long term trends and identifying dramatically high or low levels of annual recruitment. Unfortunately, recent widespread use of the Maryland seine index in population models and as a regulatory action level trigger has resulted in index values often being interpreted in a much more quantitative sense than the sampling and statistical properties of the original data sets justify. If measures of recruitment success are to continue to play a dominant role in future management strategies, much more quantitative and precise indices of juvenile abundance are highly desirable if not required.

Beacause of the mandated use of the Maryland seine index, any immediate effort to create an improved Baywide measure of striped bass recruitment must of necessity be structured around it. An obvious first step in the creation of a Baywide recruitment index should be the standardization of seining methodology between the Maryland and Virginia surveys, an effort which has been already undertaken during the course of this study.

Present within-drainage sample sizes are too low to permit meaningful comparisons between systems within years, but there is every indication that recruitment success is highly variable between drainages. Sample sizes should be increased to extent resources allow, either by adding stations, increasing sampling frequency at the presently occupied stations, or a combination of both. Effective sample size may be able to be increased without a completely commensurate increase in effort by eliminating replicate hauls in favor of more stations or more frequent sampling. Estimation errors associated with the Maryland index may be significantly reduced by applying an appropriate transformation prior to calculation of the index.

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INTRODUCTION

During the past decade large declines in the commercial landings and other indicators of Atlantic Coast striped bass (*Morone saxatilis*) stock size (Boreman and Austin 1985) have caused deep concern over the present status of these stocks. Of particular concern is the current condition of the Chesapeake Bay stock, which has been historically shown to contribute a large portion of the fish taken in the coastwide fishery (Berggren and Lieberman 1978; Van Winkle et al. (in press)). Severe restrictions on the taking of striped bass in Chesapeake waters are currently in place, including a complete moratorium in Maryland waters and six-month moratoria coupled with complex size limits and catch quotas in the Potomac and the Virginia portion of the Bay.

Estimates of juvenile abundance are presently widely utilized as the most reliable early estimator of future striped bass year class strength available and are a key element of recently developed models of recruitment and reproductive capacity of striped bass stocks. Goodyear (1985) reported a strong relationship between reported landings and prior Maryland Department of Natural Resources beach seine survey based indices of young-of-the-year striped bass abundance and concluded that such indices provided a useful measure of recruitment. Subsequently, the Maryland juvenile index has been used as an estimate of recruitment in the development of an egg deposition model (Boreman and Goodyear, 1984) and a model examining the interrelationships between juvenile and adult survival rates (Goodyear et al., 1985). Simulations run with the egg deposition model to evaluate potential effects of various fishery management strategies are presently receiving strong attention by the Interstate Fisheries Management Program bodies.

Management measures currently being implemented in an effort to halt the decline in Atlantic coastal striped bass stocks rely heavily on estimates of juvenile abundance. The recent important emphasis being placed on the Maryland juvenile index as the best available measure of recruitment has lead to the incorporation of this index as the action level trigger for the relaxation of the stringent fishing regulations currently being implemented under a new amendment to the Striped Bass Management Plan. Amendment #3 to the Atlantic States Marine Fisheries Commission's Interstate Fishery Management Plan for the Striped Bass, approved be the Commission on June 19, 1985 and taking effect July 1, 1985, includes the stipulation:

> "That the states reduce fishing mortality on the 1982 year class females, and females of all subsequent year classes, by 95% until the females of these year classes have an opportunity to reproduce at least once. This objective is intended to apply to the fishery until the 3-year running average of Maryland young-of-year index attains 8.0."

The Maryland young-of-year index is based upon a fixed-station beach seine survey conducted on the nursery grounds three times each summer. The survey was commenced in 1954 and has been conducted each year since. In 1967 the Virginia Institute of Marine Science, under funding from the U. S. Fish and Wildlife Service, began a parallel survey in the Virginia nursery areas. This program was discontinued after the 1973 sampling season due to a suspension in federal funding. In 1980, in response to the rising concern over the decline in landings, the survey was reinstituted as part of the Emergency Striped

Bass Study authorized by the Anadromous Fish Conservation Act Amendment, Public Law 96-118. Sampling has continued through the present.

With the exception of 1970, when maximal values were recorded in both states, there has been very little coherence between the annual recruitment indices generated by the Maryland and Virginia seine surveys (Fig. 1). This lack of agreement has become of special concern with the recent emphasis placed upon the Maryland index as a major element in the coastwide management strategy. If the observed differences are an accurate reflection of greatly varying annual rates of striped bass recruitment between the Virginia and Maryland portions of the Chesapeake Bay, rational management of the Chesapeake striped bass stocks will be best served by an index that is based on the entire Bay rather than just the Maryland tributaries. Conversely, if annual striped bass recruitment is relatively uniform within the Bay and the differences between the two indices are a reflection of sampling artifacts of either or both surveys, it is imperative that the causes of the discrepancies be identified and corrected. In view of the incorporation of the Maryland index into the Striped Bass Management Plan as the action level measure, it is critical that any shortcomings in the ability of such beach seine surveys to accurately reflect striped recruitment in the Chesapeake Bay be thoroughly understood.

The present report summarizes the results of an analysis of the potential causes of the differing results of the Maryland and Virginia seine surveys with respect to young-of-year striped bass. This study was undertaken as a preliminary step toward the development of a possible standardized Bay-wide index of juvenile striped bass

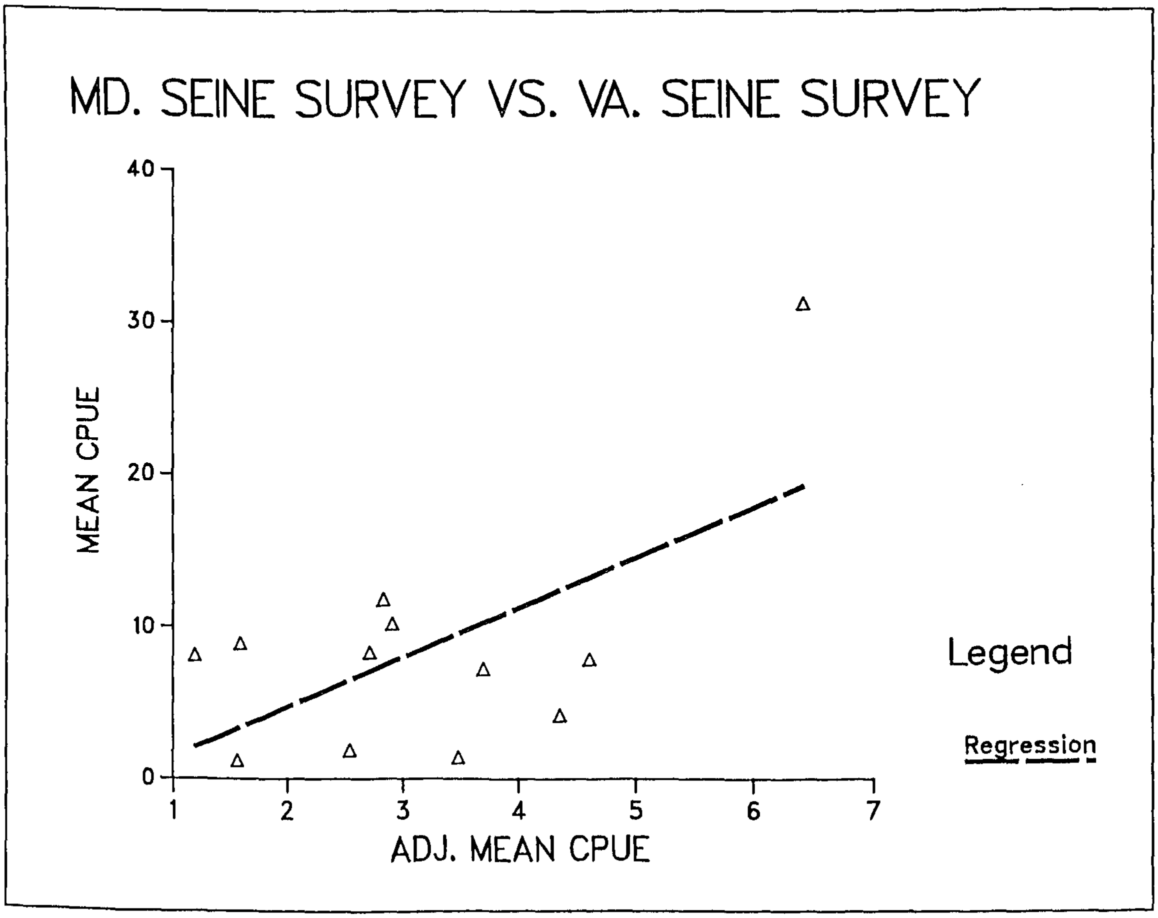

Figure 1. Annual striped bass juvenile index for the Maryland portion of Chesapeake Bay (vertical axis) regressed against that for the Virginia portion (horizontal axis), 1967-73 and 1980-85 ($r^2 = 0.37$, $p < 0.017$).

abundance. In addition to carefully examining the results of the two seine surveys, this study also included an examination of catches of juvenile (young-of-year) striped bass taken during the VIMS juvenile fish trawl surveys. These surveys have been conducted in the Virginia tributaries of the Bay since 1955, often on a monthly basis. Although the trawl surveys were not specifically designed to sample juvenile striped bass, the long time series and the fact that other states (California, New York, North Carolina) utilize trawl surveys to generate juvenile striped bass abundance indices merit a close look at this data set.

Analysis of the trawl survey data had a twofold purpose: 1) to provide an alternate measure of striped bass abundance to which the results of the seine surveys could be compared, and 2) to provide an initial evaluation of the potential of a trawl survey as an alternative or corroborative measure of striped bass recruitment in Chesapeake Bay. With respect to the second objective a special data set collected during the summer of 1978 was also analyzed. This project consisted of intense simultaneous sampling with multiple gears (16′ and 30′ bottom trawls, midwater trawl, and pushnet). The study was aimed at evaluating habitat utilization of juvenile alosids, but was conducted in the striped bass nursery zone as well. Analysis of both the regular and special trawl surveys also serves to provide a much more comprehensive picture of the geographical and seasonal distribution of juvenile striped bass than can be discerned from the seine surveys.

In addition to comparing the results and contrasting the methodological basis of each of the various aforementioned surveys, a secondary objective of this study was to perform a preliminary investigation of the influence of dominant environmental variables upon juvenile striped catches therein. This phase of the analysis also had a twofold purpose: 1) to examine if differences in environmental parameters may be responsible for the observed differences in survey results, and 2) to attempt to assess the relative importance and effects of the major environmental variables upon survey results, with particular emphasis upon environmental factors to be considered in the planning of future surveys.

Environmental influences on juvenile striped bass abundance are undoubtedly myriad and complex, and many factors not measured during the surveys probably play key roles in determining both absolute abundance and availability to the sampling methods. Many of these unmeasured factors, such as water quality parameters, could not be practically controlled for during survey design even if their effects on juvenile striped bass abundance were fully understood, which they are not (Hall 1984, 1985; Hall et al. 1984). The present evaluation of environmental influences on juvenile striped bass catches therefore has been limited to a very general consideration of parameters which are easily measurable and exhibit obvious overall influences on catch rates, such as salinity, temperature and (in the case of the trawl surveys) depth. These types of factors can and should be accounted for, both during survey design and inter-survey comparisons.

METHODOLOGY

Prior to analyses it was necessary to combine the three major data sets into a standardized data base. A schema for an SPSS (Statistical Package for the Social Sciences, Hull & Nie 1981) system file incorporating each of the recorded variables was designed and conversion programs written for entering each of the three data sets. Joseph Boone of the Maryland Department of Natural Resources kindly provided tabular summaries of the striped bass catches of the Maryland seine survey as well as additional supportive information such as project reports. The Maryland data were entered into the VIMS Prime 850 computer and then, along with the Virginia seine and trawl survey results, converted into the standardized system format.

Sampling designs and methodologies were documented for each of the three data sets. The Maryland seine survey has had by far the greatest consistency, utilizing the same gear and undergoing only moderate changes in sampling frequency and sampling locations over a 30-year period. Both the Virginia seine and trawl surveys have been subject to changes in gear and sampling methodologies, the trawl surveys to a much greater extent than the seine survey. Specific sampling protocols have been as follows:

Maryland Seine Survey - The present Maryland young-of-year striped bass index is based on average catch rates obtained at 22 fixed sampling sites located in four major sampling areas (Upper Bay, Potomac, Choptank, Nanticoke; Fig. 2) visited three times during the months of July-September. With the exception of a few sampling site relocations necessitated by physical modifications to sampling sites (by natural or anthropogenic causes) or loss of access, this sampling scheme has been constant since 1966. From 1962 to 1965 each site was visited twice each summer, while prior to 1962 only one visit was made to each site per year. Fifty-six different sites were sampled between 1954 and 1961, when the present basis of the survey was established (7 stations each in Upper Bay and Potomac, 4 each in Nanticoke and

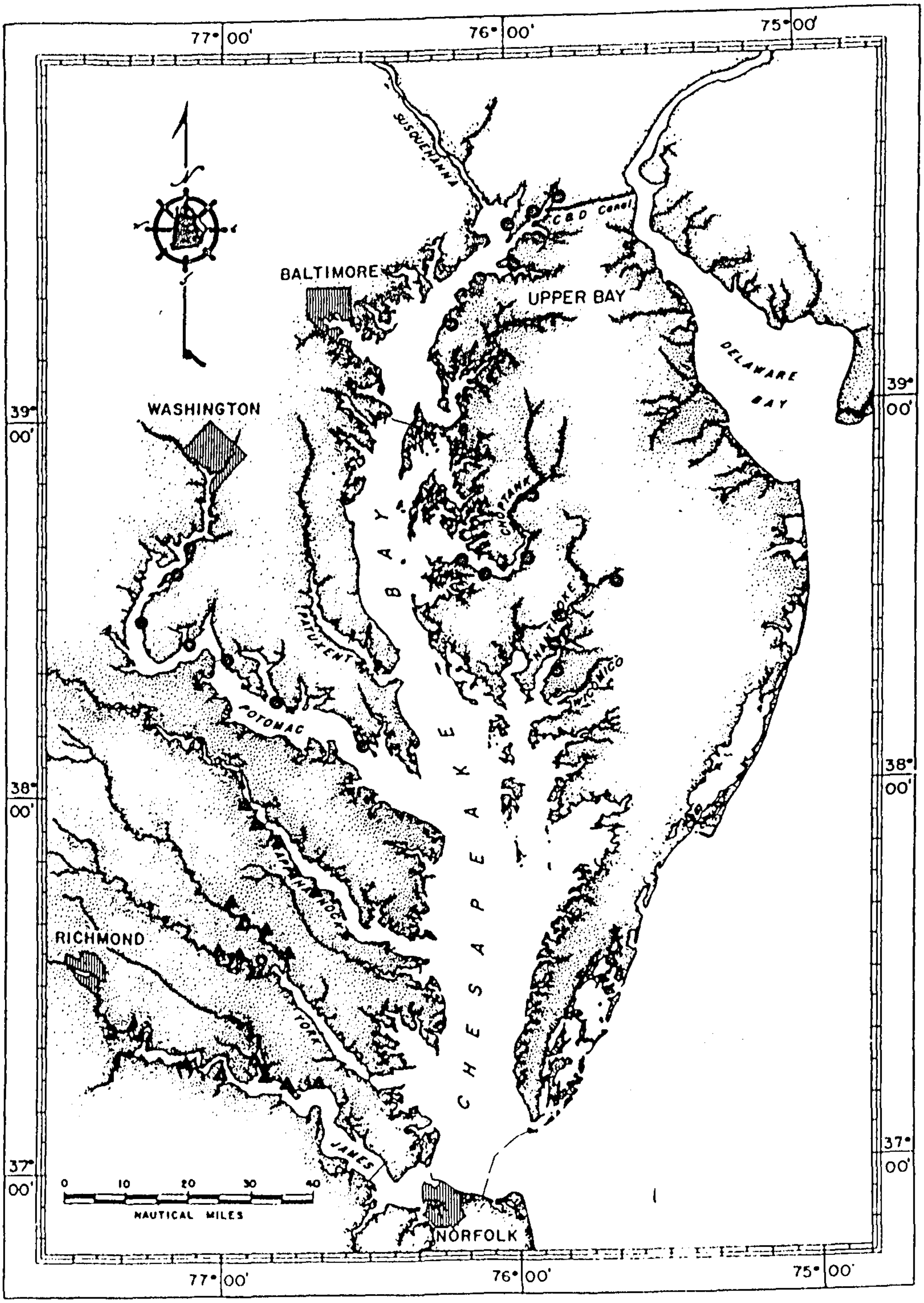

Figure 2. Sampling sites for the Maryland DNR (circles) and Virginia (VIMS, triangles) beach seine surveys.

Choptank). There was a high degree of overlap between the present sites and those sampled between 1958 and 1961, while there was only partial overlap with those sampled from 1954 to 1957. Therefore, data collected prior to 1958 was not considered in the present analysis. In recent years a number of auxiliary sampling sites have been added as a confirmatory device but these do not contribute to the calculation of the index and have also been excluded from further consideration here.

Sampling procedure at each site has remained consistent throughout the survey. Two sweeps of a commercially constructed, pocketless seine 100' long by 4' deep of one-quarter inch square mesh knotted twine are made at 30 minute intervals. The seine is deployed by setting it perpendicular from the shore and then pivoting the offshore end down-current to sweep a quadrant back to the shoreline. Fishes captured are identified, counted, and in the case of commercially important species such as striped bass, are separated according to whether they are age 0 (young-of-year) or older. Size ranges are recorded for all species and length frequencies taken for striped bass and other species of interest. Physical parameters recorded at each site include water temperature, salinity, maximum depth, tidal phase, substrate, weather conditions and type and amount of aquatic vegetation. The striped bass juvenile index is calculated as the arithmetic mean catch per seine haul of young-of-year individuals. In the past an alternative index wherein the overall index value is computed by weighting the index values for each of the four major sampling areas according to the historical commercial landings from each system has been used (Heimbuch et al. 1983), but since the simple arithmetic index is that to which the management plans are tied and also that used in the recent population models it was the only measure used in the present analysis.

Virginia Seine Survey - The seine survey initiated in Virginia in 1967 was largely modeled after the Maryland program, but some modifications were made. Instead of making two seine hauls during each visit to each site, only one haul was made at each station per visit but sampling was conducted on a bi-weekly rather than monthly basis, and sampling was extended through the month of October. As in the Maryland survey a 100′ long, one-quarter inch square mesh seine was used, however the Virginia seine was 6′ in depth, knotless construction, and had a 6′ x 6′ pocket sewn in the center. Techniques of deployment and retrieal were identical to those of the Maryland survey. Despite the difference in the depth of the two seines the effective area fished was the same in both surveys; i.e., if water depths greater than four feet are encountered prior to fully extending the seine perpendicular to the shoreline, the manual haul must be broken off along the four foot contour in order to be effectively pulled through the water. This topographically necessitated modification to the hauling procedure must be undertaken at only a small percentage of the Maryland stations but is required at about half of the Virginia sampling sites. Here, the primary nursery zones tend to be located in the narrower, upper portions of the major river systems as opposed to the wider, more gently sloping reaches inhabited in the Upper Bay.

Twenty-one fixed sampling sites were established during the 1967 sampling; six in the James drainage (James and Chickahominy rivers), eight in the York system (York, Pamunkey and Mattaponi rivers) and seven on the Rappahannock River (Table 1). In 1969 a seventh station

Table 1. Number of collections summarized by station and year for Virginia seine survey.

River Station	Year 19- 67	68	69	70	71	72	73	80	81	82	83	84	85	All
James														
J15	8	8	8	8	8			6						46
J20	6	8	8	8	8	8	9	5						60
J22	1													1
J23				8	8	8	9							33
J25	8	8	8	8	8	8	9	6	8					71
J27						8	9	6	8	6	6	6	8	57
J29			9	8	8	8	9							42
J35	7	8	8	8	8	8	9	7						63
J36									8	6	6	6	8	34
J46								5	8	6	6	6	8	39
J50	6	8	8	8	7									37
J53								5						5
J57									8	6	6	6	8	34
J67									6					6
Chickahominy														
C 0									8					8
C 1	7	8	8	8	8	8	7	8	8	6	6	6	8	96
C 3								1	6	6	6	6	8	33
C 4								2						2
C 6								8	2	1				11
C 9									8					8
C12								4						4
C16								4						4
York														
Y 4	6	8	8	8	8			7	6					51
Y10						7	1							8
Y11						8	1							9
Y12	6	8	8	8	8	8	9	7						62
Y14						8	1		8					17
Y16	1													1
Y17						16	2							18
Y18								1						1
Y19	5	8	8	8	8	8	2	6						53
Y21						8	1							9
Y23	1					8	1							10
Y24									8	6				14
Y25	6	8	8	8	8	8	7	7						60
Y26						8	1							9
Y27						8	1							9
Y28	7	8	8	8	8	8	10	6						63

Table 1. (cont.)

River Station	67	68	69	70	71	Year 19- 72	73	80	81	82	83	84	85	All
Mattaponi														
M33									8	6	6	6	8	34
M35						8	1	6						15
M41						8	10	5	8	6	6	6	8	57
M42								1						1
M44	6	8	8	8	8	8	9	7	8	6	6	6	8	96
M47									8	6	6	6	8	34
M48	2	8	8	8	8	8	8	6						56
Pamunkey														
P35						8	1							9
P40						8	1							9
P42									8	6	6	6	8	34
P44								5	8	6	6	6	8	39
P46						8	1	4						13
P51									8	6	6	6	8	34
P52	7	8	8	8	8	8	10	7						64
P55									8					8
Rappahannock														
R10	8	8	8	8	8									40
R14	8	8	8	8	8			5	6					51
R18	7	8	8	3										26
R19									2					2
R24				4	8	8	7	6	8	5	2	6	6	60
R28	8	8	8	8	8	8	7	6	8	6	4	6	8	93
R32						8	8							16
R37	8	8	8	8	8	8	8	5	8	6	6	6	8	95
R39								1						1
R44	8	8	8	8	8	8	8	4	8	5	6	6	8	95
R50	8	8	8	8	8	8	8	5	6	6	6	6	8	95
R72								1						1
R86								1						1

was added in the James, and the following year still another station was added in the James and one of the York stations had to be relocated due to a change in property ownership. The passage of tropical storm Agnes in June of 1972 resulted in a substantive revision of the station pattern. In order to assess the effect of this major environmental perturbation, it was decided that one system should be intensively sampled, the York being chosen for logistical reasons. Thirteen new stations were added in the York system, while the lowermost and uppermost James stations and the two lowermost Rappahannock stations were dropped. A mid-reach station was added to both of the latter two rivers. After the first sampling cycle in 1973, all but one of the newly added stations in the York system were discontinued, while the moderately modified station pattern adopted the year before was continued in the other two systems. Sampling ceased after the 1973 season.

With the resumption of the survey in 1980, the decision was made to standardize gear between the Maryland and Virginia surveys. Unfortunately the newly ordered Maryland type seine was not delivered in time for the first sampling cycle in July and the 6 foot deep bag seine had to be used. During the second cycle both nets were fished alternately at each station in the York River system to estimate relative efficiencies of the two nets. The Maryland style net was used for the remainder of the sampling season. Sampling was conducted on a tri-weekly basis for a total of five sampling periods, with one haul being made at each of thirty fixed stations per visit. The stations occupied largely corresponded to those sampled during the latter part of the earlier survey plus a few new stations added in the Chickahominy River. A few stations had to be relocated due to a loss of access, while a number of others were found to be extremely difficult to sample due to siltation.

These problems with land access and soft bottom, coupled with the steep beachfront at many of the sites, led to a major change in sampling technique commencing with the 1981 sampling season. Use of a 6' deep bag seine was reinstituted, and deployment of the seine was changed from the walk around method to a haul seining technique wherein the seine was set parallel to shore at a distance of approx. 100' from a small boat and then hauled to shore by means of rope bridles attached to the brails. Twenty-seven stations were visited on a monthly basis July-October and, as is done in the Maryland sampling, two replicate tows were made during each visit. Several stations which had undergone substantial physiographic change since the earlier survey were relocated to nearby beaches not accessible by land which were considered to be more typical of previous conditions. Stations dropped from the 1980 sampling included two in the lower James and two in the York proper. Three stations were added; one in the Chickahominy River, one in the upper James and one in the upper York system (mile 55 on the Pamunkey). This continuing process of discontinuing sampling at downriver sites in favor of upriver locations reflected a growing recognition that the primary striped bass nursery areas in the Virginia tributaries are considerably further removed from the river mouths than those in Maryland.

Sampling design and protocol have remained the same since 1981 but level funding in the face of rapidly escalating costs forced cutbacks in total sampling effort in 1982 and 1983. Monthly sampling was restricted to July through September in 1982, and only 19 stations were occupied. Those dropped consisted largely of the less productive downstream stations, primarily in the York. In 1983 the last station in the York River proper was discontinued, leaving eighteen stations which have been continued through the present. During 1985 sampling periodicity was intensified to tri-weekly, however the passage of Hurricane Gloria in late September precluded completion of the fifth and final planned sampling cycle.

Sample processing and physical parameters recorded with each sample have remained essentially the same as in the Maryland survey. During the early Virginia survey dissolved oxygen concentrations were also taken with each sample, but this was discontinued when no significantly depressed levels were detected. The only other significant difference in sample processing is that length frequencies for fish of all species have been recorded in the Virginia surveys during most years, rather than just for commercially important species.

Because of the changes in sampling design, calculation of an historical index of Virginia striped bass juvenile abundance obviously cannot be based simply on the data as originally recorded. Because sampling in the downstream portions of the mainstem rivers has been discontinued in recent years and the sampling season shortened, the earlier data sets have been reduced to include only samples collected within the same time frame (July-Sept.) and those portions of the rivers presently sampled, prior to calculating index values (Colvocoresses 1984). While this procedure has removed an obvious source of bias between years, the index values calculated from this reduced data set may still be beset with biases introduced by the changes in sampling procedures, particularly the effects of introducing replicate samples and changing the net deployment technique. Possible impacts of these changes on the index values will be discussed below.

The Virginia index values are calculated somewhat differently than the Maryland index. While the Maryland index is an arithmetic mean catch per seine haul, the Virginia index is calculated first as the geometric mean catch per haul and then adjusted to the comparable arithmetic value for purposes of direct comparison with the Maryland survey. The logarithmic transformation was applied to normalize the data and reduce the sample variance. The frequency distribution of juvenile striped bass catches in the Virginia nursery grounds is highly skewed, reflecting a highly contagious distribution (Colvocoresses 1984).

<u>Virginia Trawl Surveys</u> - VIMS began regular monitoring of juvenile fish populations in the Virginia tributaries and lower Chesapeake Bay in 1955, when sampling was commenced at fixed, mid-channel stations spaced at five mile intervals from the mouth of the Bay along a transect up the York River system, continuing up the Pamunkey River to river mile 50. Sampling was conducted with an unlined, 1 1/2" stretch mesh, 30′ semi-balloon trawl towed along the bottom for either 15 (lower portions of rivers and Bay) or 7.5 (upper rivers) minutes at each station. Sampling was attempted on a monthly basis after April of 1956, but for logistical reasons not every month could be sampled and some stations were not successfully completed during certain sampling periods, particularly during the winter months.

In 1964 sampling was expanded to include the lower 40 miles of the James River, again utilizing fixed stations spaced at about five mile intervals. Sampling was further extended into the lower 40 miles of the Rappahannock River the following year, with the gear and sampling design remaining the same. This scheme of sampling (monthly, mid-channel, fixed station sampling in the lower Bay and three mainstem major tributaries with a 30' unlined trawl) was continued until August of 1972, when a series of major changes in gear and sampling strategy were initiated.

In July of 1970, in addition to the regular survey described above, regular sampling utilizing a smaller (16') otter trawl with a liner (1/4" bar mesh) sewn in the cod end was commenced in two of the smaller tributaries (Piankatank River and Mobjack Bay system) of the Lower Bay. The success encountered with this gear prompted the implementation of parallel sampling along with the main survey in the York River. Starting in July of 1971, shoal water (5-10') stations were established on both sides of the middle four (at river miles 10, 15, 20 and 25) regular channel stations and sampled on the same monthly basis using the 16' lined net. The success of this program led to the expansion of sampling with the smaller trawl to include the entire York River system, utilizing a stratified random design covering all waters deeper than 3 feet. This new survey was implemented in July 1972 and completely supplanted the fixed station, mid-channel survey two months later. Sampling in the James and Rappahannock was continued as previously thru the end of 1972, at which time sampling with the unlined 30' trawl was terminated.

In June of 1973 a completely new regimen of sampling was begun. The entire lower Chesapeake Bay (Virginia waters) as well as the three major river systems were sampled using a <u>lined</u> (1/4" bar mesh) 30' otter trawl and a stratified random sampling design. Because of the intensity of sampling, sampling periodicty was changed from monthly to semi-annually (except for the random survey using the 16′ net in the York, which was continued on a monthly basis until the end of 1973). Intensive summer and winter random surveys using the 30′ lined trawl were continued through the winter of 1978-79. During the 1973-74 winter survey sampling was expanded into the Potomac River and sampling was extended upriver in the other three river systems as far navigation requirements would allow. During the 1975 summer survey supplementary sampling with the 16′ net was added in order to sample waters too shoal (<3 meters) to be sampled with the larger net (and hence larger vessel). Because lined nets tend to clog with bottom debris much faster than unlined nets, tow times using the lined nets have been restricted to five minutes or 1/4 mile measured distance (approx. 6 min. at normal towing speed in slack water).

After the winter of 1978-1979 monthly sampling was resumed and areal coverage was again restricted to the channels of the lower portions of the major river systems. Monthly sampling has remained in effect since May of 1979, but there have been some seasonal changes in sampling design and gear as responsibility for the survey was apportioned seasonally between two different groups through 1985. Fixed station sampling, utilizing the same stations occupied from 1955-72, was done during the months of May thru November. From December of 1979 thru April of 1982, stations occupied during the other months of the year were selected randomly, but selection of stations was limited to the channel and stratification was based on five mile blocks, resulting in a very similar distribution of effort. Since April of 1982 the same fixed stations have been sampled throughout the year. Although the recent trawl surveys have returned to the same sampling design as was originally implemented, the gear used is considerably different. The lined 30' trawl has remained in use and the addition of a tickler chain was made with the resumption of monthly sampling (although temporarily not used December 1979-April 1980).

Hydrographic and meteorological parameters recorded with the trawl surveys have been largely the same as those taken during the seine surveys, with an added dimension associated with depth of sampling. Both bottom and surface water temperature and salinity have been measured at or near each station since the surveys' inception, and surface and bottom dissolved oxygen concentrations have been monitored at most stations since the mid-sixties. Tow duration and direction relative to tidal current are other relevant variables recorded which were not applicable to the seine surveys.

In contrast to the seine surveys, which were designed specifically to monitor yearclass strength of striped bass, much of the data obtained during the trawl surveys were collected from areas and depths not inhabited by juvenile striped bass during the period of collection. Futhermore, striped bass catches taken during the trawl surveys were not separated by age (young-of-year or older) as during the seine surveys. As a result, computation of a trawl-survey derived young-of-year index from this data set required retroactive dissection of catches into age classes (zero and one-plus), using length frequencies and subsequent identification of the season and areas which provided the largest and most consistent catches of juvenile striped bass.

In order to separate catches according to age, composite length frequencies were generated for each month and examined for modal separation between the age 0 and age 1 yearclasses. These data were compared to length-at-age values reported in the literature to establish a 'cutoff' length which best separated the two yearclasses during each month. The number of striped bass taken during each tow was then corrected to the number of young-of-year striped bass per tow according to the length frequencies taken with each catch. If all fish were measured, those larger than the cutoff value were deleted from the catch; if only a subsample was measured the total number caught was proportionally reduced according to the number of measured fish equal to or smaller than the cutoff length. Samples for which length frequencies were not taken or available were deleted from the data set, including all data from 1955-57 and 1959-60 surveys.

Relative catch rates and the percentage of tows producing young-of-year striped bass were then tabulated by gear type, year, river, month, depth and river mile. These tables were then examined in order to determine the time of year and specific areas yielding the most consistent catches of juvenile striped bass throughout the data set period. In contrast to the seine surveys, which were specifically designed to optimize catch rates of young-of-year striped bass and provide an index of recruitment, the trawl surveys were designed to provide blanket sampling of a broad spectrum of fish and crustacean species. As a result, large portions of this data set bear little or no applicability to the relative abundance of individual species, particularly those (such as striped bass) that exhibit seasonal habitat changes or migrations which carry them in and out of the area of sampling coverage. The various changes in sampling area, periodicity and design further complicated the calculation of a meaningful abundance index. Simply calculating average catch-per-tow for all or most of the data set, as was done for the seine surveys, would produce misleading results. It was therefore necessary not only to identify the seasons and areas wherein young-of-year striped bass were most consistently available to the trawl surveys, but also to assure that a commonality of sampling (with respect to time of year, areas, gear, depths sampled, etc.) existed throughout the time period for the data selected.

Effects of Environmental Parameters - As noted above, the objective of the present evaluation of environmental influences on juvenile striped bass abundance is to provide a general characterization of environmental parameters which may exert an overall large scale effect on survey results. Catch rates have been summarized across the ranges of the major environmental variables recorded during the surveys by partitioning these ranges into intervals and calculating the mean catch-per-effort for each interval and the associated variance around each of these means (expressed as 95% confidence intervals as estimated by $\pm$ two standard errors of the mean). Reference to "significant" differences between means in this context will be restricted to cases of non-overlap by these confidence intervals.

Following this descriptive phase, stepwise linear regression techniques (Draper and Smith 1966) were performed to provide a preliminary assessment the relative importance of the environmental variables on survey results and to examine the possibility of interactive effects. Multiple regressions were performed using the SPSS (Statistical Package for the Social Sciences) package (Hull and Nie 1981).

RESULTS AND DISCUSSION

Interrelationships Between Survey Results

As previously noted, there are two obvious possible explanations for the observed differences in the Maryland and Virginia beach seine survey annual recruitment indicies; either relative production of young-of-year striped bass varies greatly in different portions of the Chesapeake Bay within years, or either or both surveys are providing very poor or inaccurate measures of actual juvenile abundance. The first possibility may be investigated by examining inter-drainage variability in annual indices within each of the two surveys. Both of these surveys encompass several river drainages which form the basis for four recognized sampling areas within the Maryland portion of the Bay (Potomac River, Upper Bay system, Choptank River, Nanticoke River) and three such areas in the Virginia portion (James River system, York River system, and Rappahannock River).

Comparison of the annual young-of-year striped bass indices for each of these sampling areas (Figs. 3 and 4) show very little of the consistency which might be expected if relative recruitment varied uniformly throughout the Chesapeake Bay between years. Although all seven areas showed comparatively high indices in 1970, maximal values were recorded in only three areas (Upper Bay, Choptank and James) and this degree of coherence was not seen in any other year. Often, relative index values have been dramatically different between areas. For example, the 1965 Maryland survey resulted in a near maximal index for the Nanticoke river, a near minimal value for the Upper Bay, a low value for the Potomac River and about average in the Choptank. This

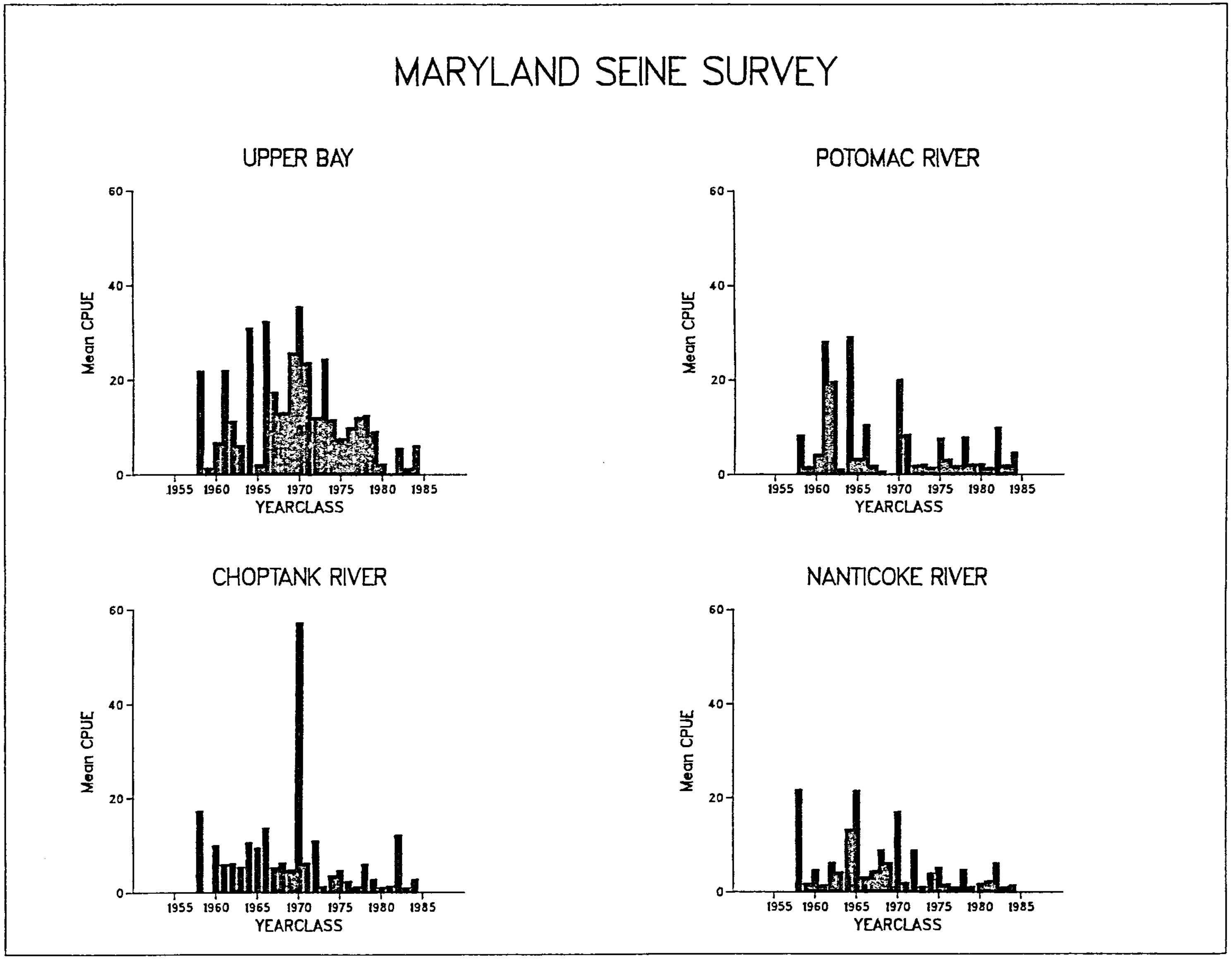

Figure 3. Annual Maryland juvenile striped bass mean catch per seine haul broken down by sampling area, 1958-1984.

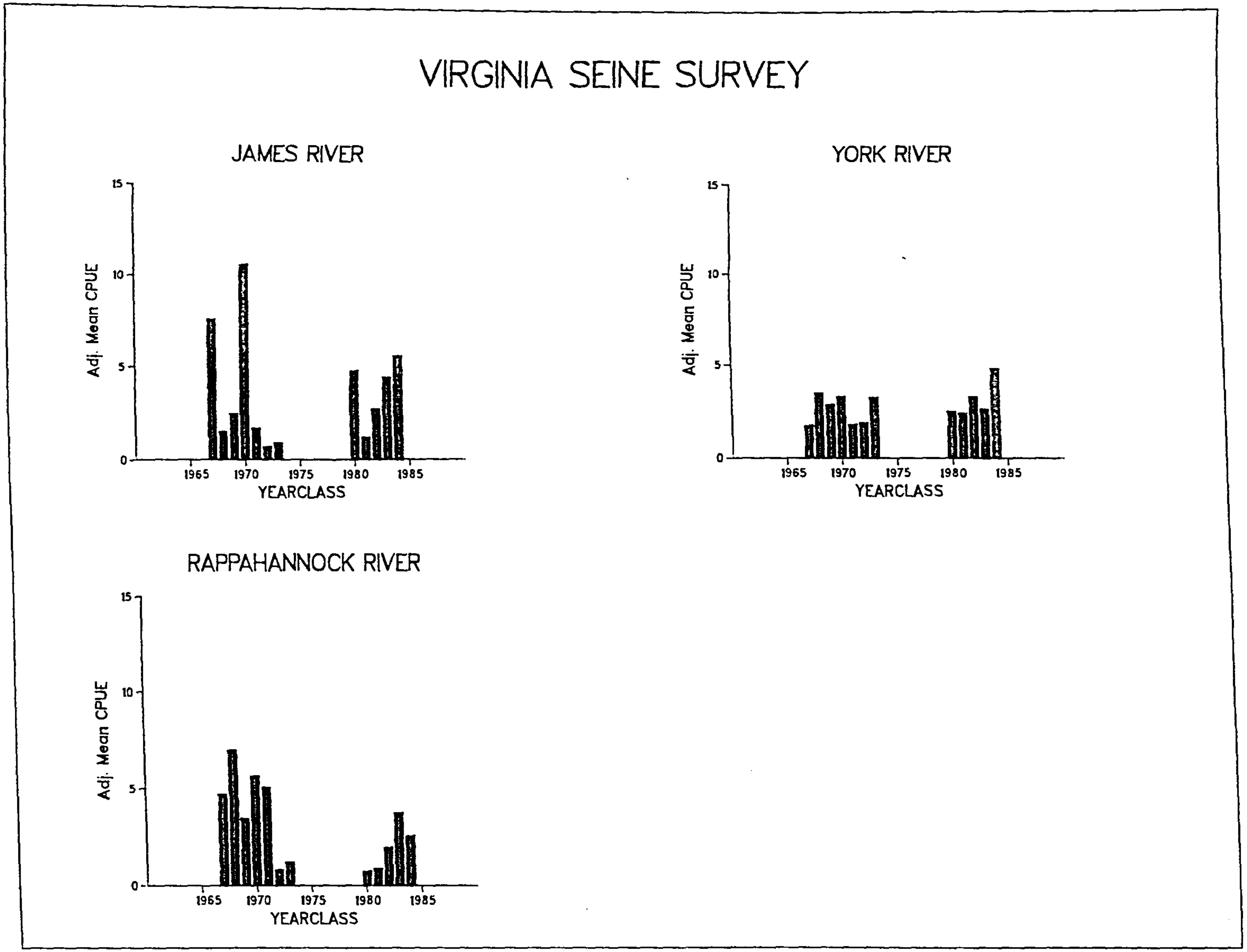

Figure 4. Annual Virginia juvenile striped bass adjusted mean catch per seine haul broken down by sampling area, 1967-1973 and 1980-1984.

same type of inconsistency is evident in the Virginia survey, such as during 1968 when the Rappahannock displayed it's maximal value, the James one of it's lowest indices and the York was about average.

If these surveys do provide a valid measure of relative annual striped bass recruitment, it is evident that there are large differences between the different systems within the Bay with respect to either the degree and success of spawning, early survival or both within years. Furthermore, there is no evident trend for geographically proximal systems to exhibit any greater consistency with respect to historical patterns of index values than geographically separated areas, as might be expected if climate scale environmental variables were exerting a significant effect on striped bass recruitment success. The large and apparently unrelated fluctuations of the annual recruitment indicies of the different Chesapeake Bay subsystems indicate strongly that either striped bass recruitment success is greatly influenced by local scale biological and/or environmental variables or that the inconsistencies observed are an artifact of the methodology used to generate the index values. The latter possibility must be dismissed before the prior conclusion may be drawn.

Two separate approaches were taken to investigate whether the annual index values for the different systems reflect bona fide variations in local recruitment success or show such disparate historical patterns as the result sampling variability. The first approach was to examine the internal variability of the data sets for each river system, while the second approach was to attempt to validate the results of the Virginia seine survey by relating the results of that that survey to a second, independent measure of striped bass juvenile abundance in those river systems (the trawl survey catches).

Both the Maryland and Virginia overall annual juvenile indexes have been shown to exhibit a high degree of sample variability and hence low precision (Heimbuch et al. 1983, Colvocoresses 1983; Figs. 5 & 6). If there are indeed significant differences in relative spawning success within the different river systems of the Chesapeake Bay, the low precision observed may be a result of combining data from subpopulations which are having very different annual rates of recruitment. If this is the case, annual sample variability within each system could be expected to be lower than the overall sample variability. Conversely, if the high variability in the overall sample is simply a direct reflection of a very high natural variability in juvenile distribution, the sample variability within each system can be expected to be considerably higher (due to smaller sample size) than the overall sample variability within a given year, and the differences in relative recruitment observed between systems may be a result of a sampling artifact resulting from drawing a relatively small sample from a population of great variability.

Comparison of the coefficients of variation (standard error of the mean divided by the mean) for the composite annual indices for each state with those for the indices for the individual subsystems reveals a varying pattern of relative sample variability (Appendix Tables 1 & 2). The coefficients of variation for the individual river systems were almost uniformly higher than those for the combined annual indices, but not to as great a degree as would be expected if there were no statistically significant differences between systems. If the coefficients of variation for the individual river systems are

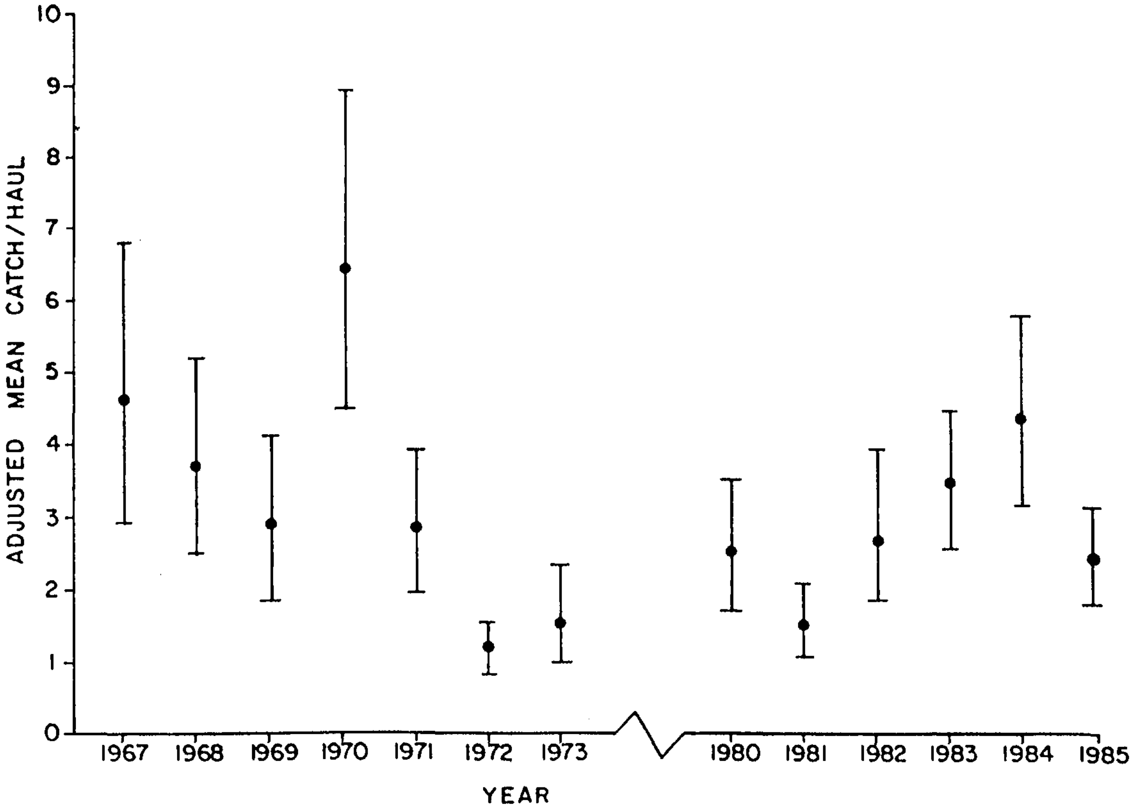

Figure 5. Annual Virginia juvenile striped bass adjusted mean catch per seine haul. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean.

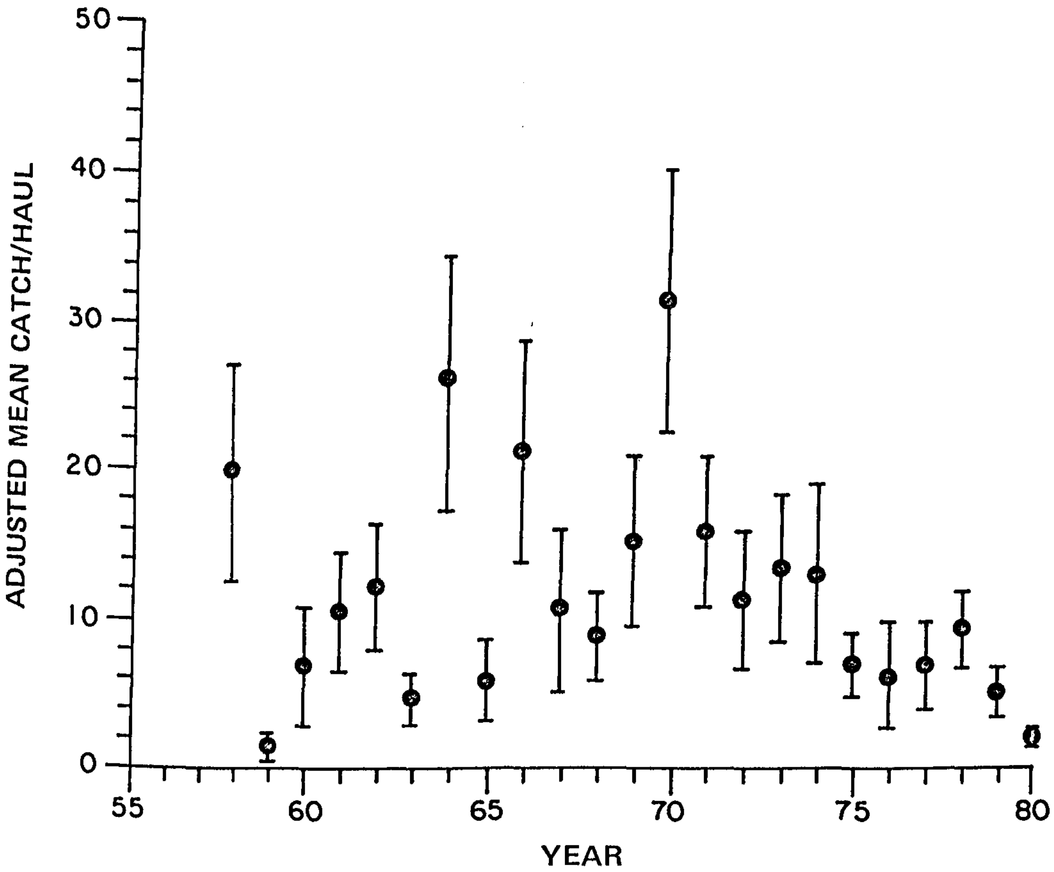

Figure 6. Annual Maryland juvenile striped bass adjusted mean catch per seine haul. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean (from Heimbuch et al. 1983).

compared to those which the composite annual indices would exhibit if they had the same mean and variance but were drawn from the smaller sample size of the individual systems, the coefficients of variation for the individual systems are generally smaller (102 of 147 cases). This observation is consistent with the findings of Heimbuch et al. (1983), who in performing an analysis of variance testing the effects of river, station and sampling period on the Maryland index values for 1966-80, found significant differences in mean catch per haul between rivers in many years.

From the above it is apparent that although there are evident real differences in annual recruitment success between river systems, there is also a very high level of variability in the distribution of juveniles which may be strongly contributing to the observed differences in index trends between these systems as well. Furthermore, there is evidence that as well as being highly contagiously distributed within each system, juvenile striped bass are probably not randomly distributed with respect to the fixed sampling sites. Heimbuch et al. (1983) also found significant station within river effects during the analyses of variance mentioned above, indicating that some stations may be better habitat for juvenile striped bass than others. The historical mean catch rates for each station show as much as an order of magnitude difference within river systems (Figs. 7 & 8). It is evident that at least for some systems within some years, the statistical assumption that the seine catches represent random samples of the overall population (either within a given subsystem or for either survey as a whole) is not met, and therefore the conventional statistical parameters generated from these data must be considered as biased and potentially invalid.

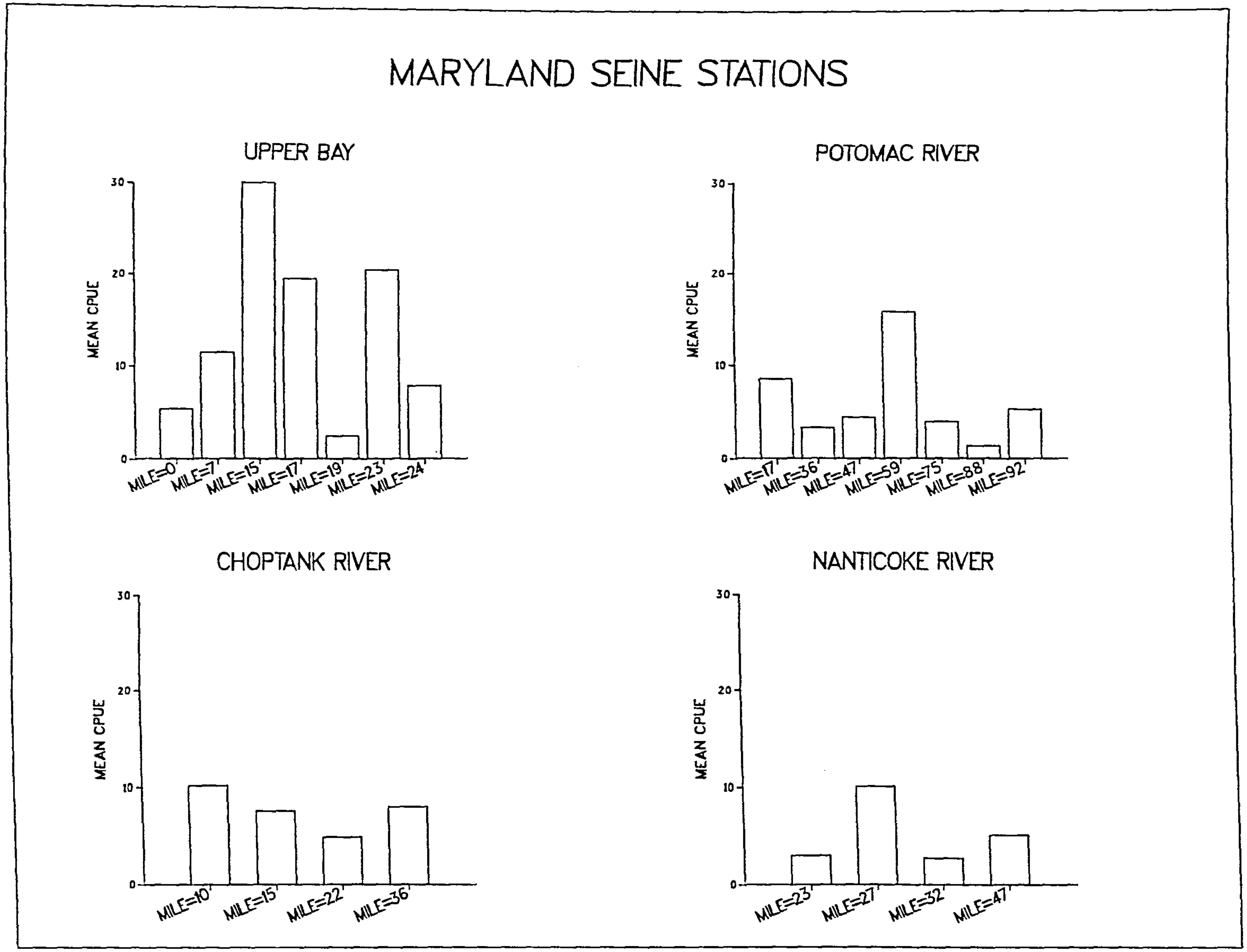

Figure 7. *Annual Maryland juvenile striped bass mean catch per seine haul* broken down by sampling site, 1958-1984.

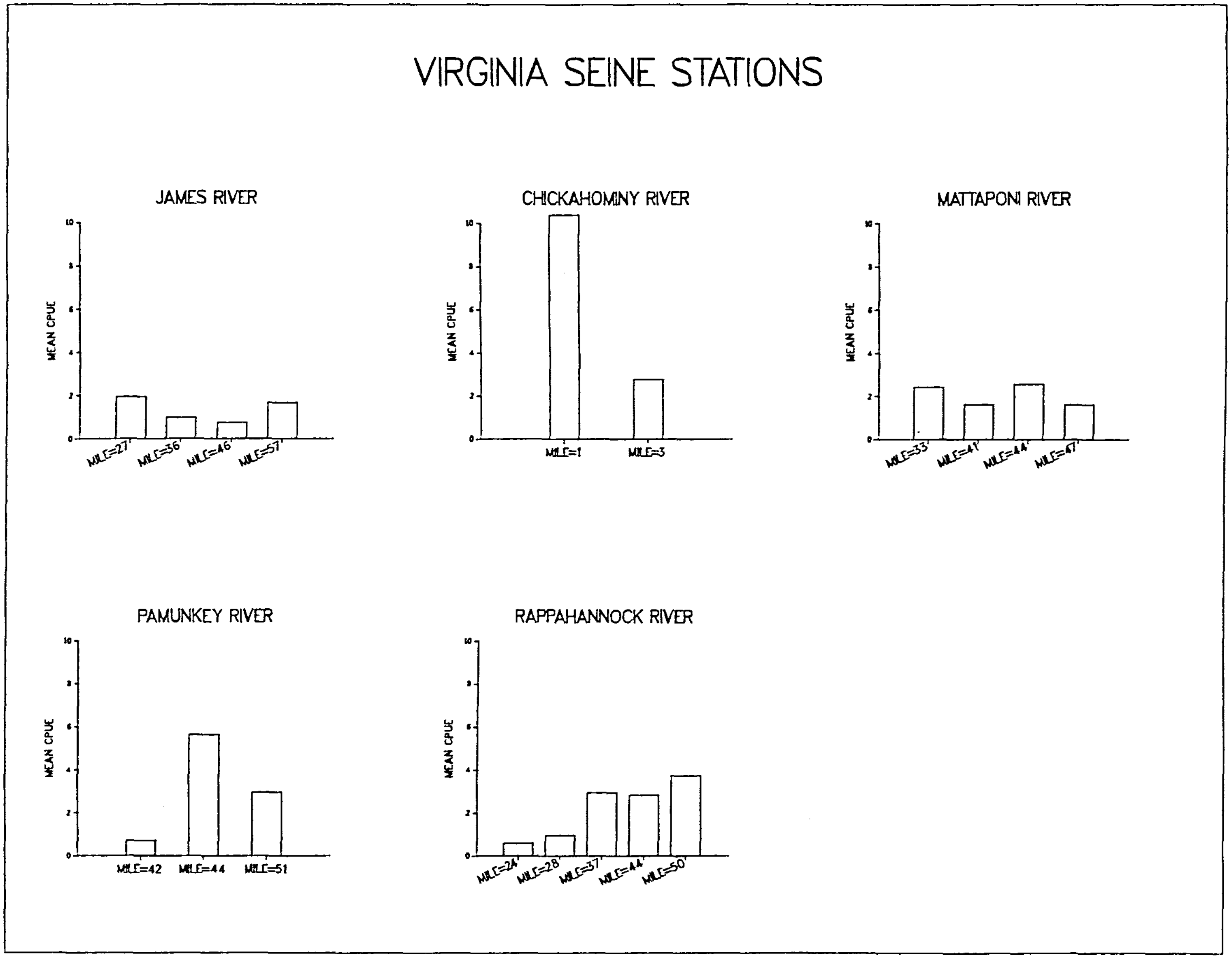

Figure 8. Annual Virginia juvenile striped bass adjusted mean catch per seine haul broken down by sampling site, 1967-1973 and 1980-1984.

The above analyses strongly imply that both real differences in relative annual recruitment and the low precision (and possibly biases) in the estimation of the respective annual indices have lead to the lack of correlation between the results of the Maryland and Virginia juvenile striped bass surveys. Partitioning the cause of the differences between these two sources is at once very important for the interpretation of the results of these surveys and also very difficult to establish within the framework of the available data. The Maryland index as a measure of relative striped bass recruitment has widely been regarded as validated by the work of Goodyear (1985). Similar validation of the Virginia index would imply that the observed differences in the trends of the two recruitment indices were at least to an important degree a real reflection of differential spawning success in the two states' waters. Unfortunately, the shorter (and broken) time series provided by the Virginia seine survey, coupled with the recent corruption of landings data by rapidly escalating fishing restrictions, obviates a meaningful repetition of Goodyear's multiple correlation analyses. Therefore an alternate measure of juvenile striped bass abundance, the results of the trawl surveys, were used in an attempt to validate the results of the seine survey. While admittedly consistent results between these two methodologies would not establish a capability of projecting later adult abundances, such consistency would strongly indicate that the Virginia seine survey is generating a reliable estimate of first year relative abundance and therefore differences with the Maryland survey are unlikely to be largely the result of estimation error.

As noted above, retrospective construction of a measure of juvenile striped bass abundance from a set of surveys of varying gear and sampling design required a complex and sometimes arbitrary reduction of the overall data set. The initial problem was partitioning of the striped bass catches into young-of-year and older fish. Growth rates of age zero and age one striped bass in Virginia waters are highly variable, as was evidenced by the composite monthly length frequency (Fig. 9). Disjunct size modes between newly metamorphosed young-of-year and one year old striped bass only persist from May, when the new juveniles first appear in the catches, until July, when rapidly growing young-of-year may achieve the same size as slower growing individuals who have lived a year longer. By September there is clear overlap, while after September it is difficult to distinguish the one year old mode as those fish become less and less vulnerable to the trawl with increase in size. Examination of monthly size frequencies (Appendix Figures) indicated that in part the overlap seen in the fall months was the result of combining data across years when average growth rates may have been different, but since there was an insufficient number of fish measured in many years in order to determine year-by-year length separations, composite cutoff values were estimated, with the realization that they would not be precisely accurate for all years. The cutoff values established ranged upward from 80 mm (FL) in May to 200 mm in December, after which growth appears to temporarily cease for the remainder of the winter.

Examination of the subsequently produced tabulations of young-of-year catches revealed that the largest and most consistent catches were taken during the winter months (December-March) in the deeper portions of the lower mainstem portions of the three river systems. Catch rates and depth distribution appeared to be much more inconsistent in December than during the later winter, therefore the

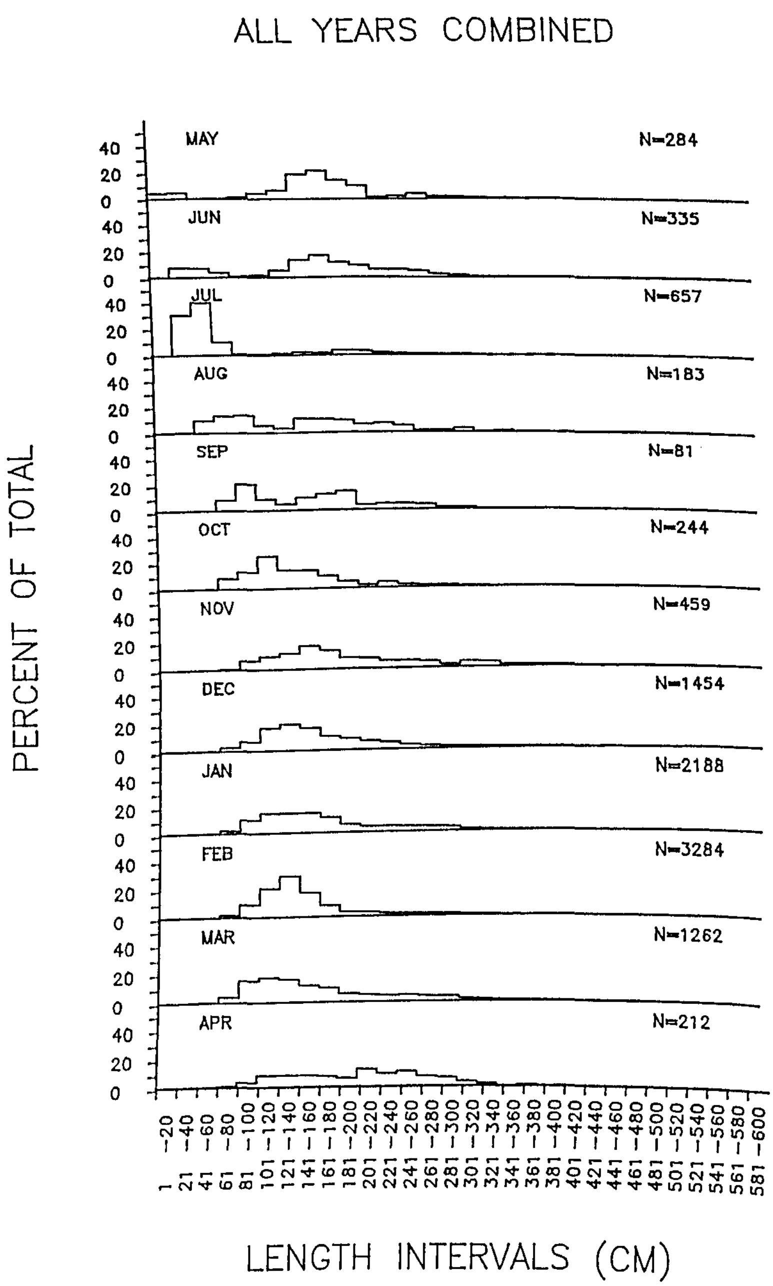

Figure 9. Composite monthly length frequencies for striped bass taken during the VIMS trawl surveys, 1961-1985.

decision was made to incorporate only data from January thru March into the final data set. This is the same time frame used by Grant and Joseph (1969) for assessing relative yearclass strength of striped bass taken during the 1967-68 trawl surveys.

The data set was further restricted to samples collected from depths greater than 5 meters within a range of latitude and longitude declared to encompass the primary overwintering ground in each system (James, York and Rappahannock) based on inspection of the data matrix (about river mile 5 to river mile 40 in each river). Very few young-of-year striped bass were taken in any of the 16′ trawl winter samples, therefore the data set was further restricted to include only the 30′ trawls. This resulted in there being no sample for the winter of 1973, when only the 16′ trawl was used, but avoided the problem of mixed gears within years.

The resultant index of juvenile striped bass abundance calculated from this reduced data set (Fig. 10) represents the best overlap between the distribution of striped bass in Virginia waters during their first year and the composite sampling efforts of a number of differently motivated and organized projects. Although all attempts were made to use a 'common denominator' approach in establishing the data set, intrinsic and important differences still remain both between and within years which must be kept in mind when either evaluating trends in this index or comparing it to another data set. Effort was standardized to a 5 minute tow by multiplying catches by the proportional duration of the tow, a procedure which undoubtedly enters another source of bias into the data set, but which is the most reasonable approach in the absence of comparative data. Of even greater potential effect, the very major gear modification of adding a

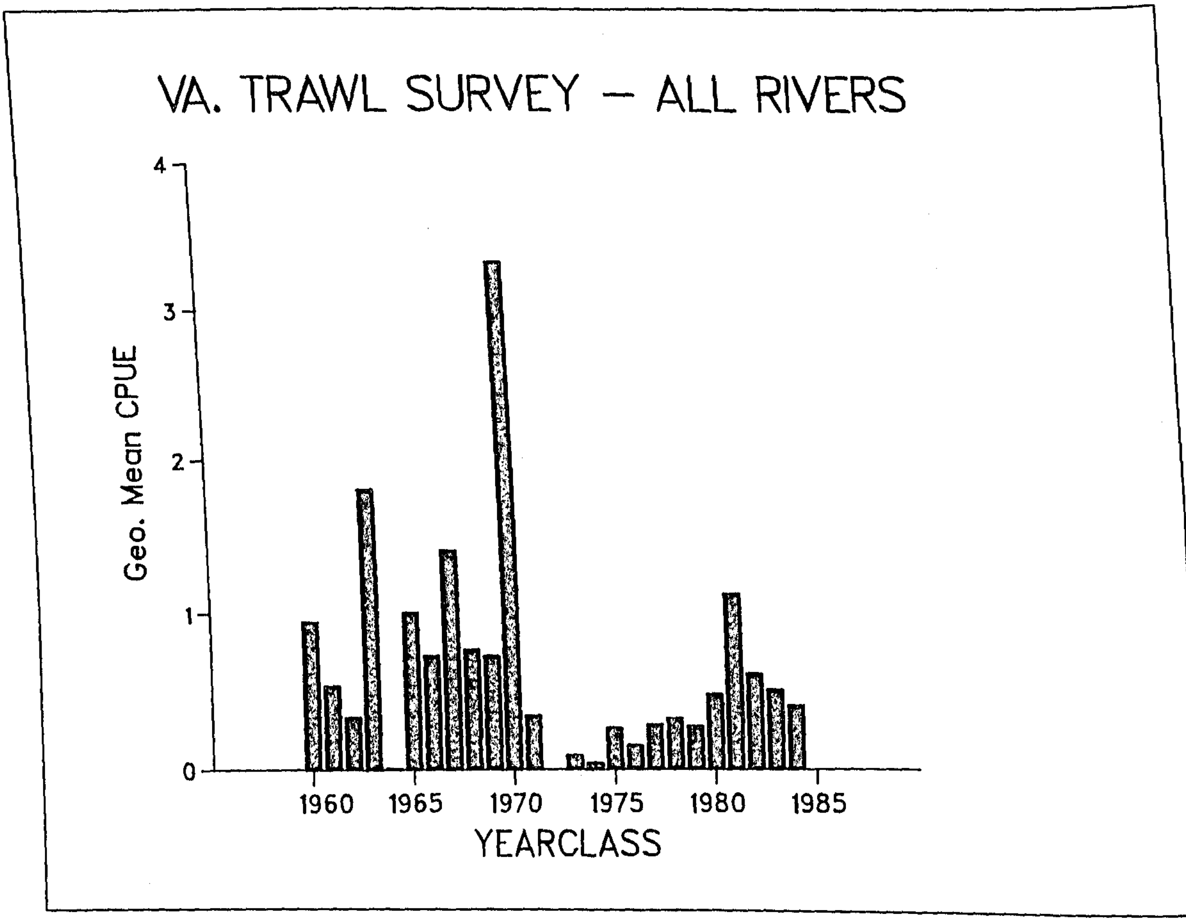

Figure 10. Annual geometric mean catch per tow of young-of-year striped bass taken on the primary overwintering grounds during the VIMS trawl surveys, 1961-85.

smaller mesh liner to the net after 1973 may have had a significant effect with respect to the catchability of young-of-year striped bass.

Comparison of the composite monthly length frequencies for the periods when the unlined and lined nets were used show evident differences (Fig. 11). A considerably higher proportion of young-of-year individuals in summer month catches after the liner was added indicates, not unexpectedly, that the lined net is much more efficient for the capture of small individuals. Since the summer data were not used in the calculation of the present index, this obvious difference is not of immediate concern, but there is a similar (although much less pronounced) trend in the composite length frequencies for the winter months towards higher proportions of smaller individuals. Since by the winter months most young-of-year striped bass are large enough to be caught in the unlined net, the difference in size frequencies may be a reflection of an increased ability for larger fish to avoid capture when the lined net, with it's much greater back pressure, is used. Until such time as as a rigorous gear comparison study can be performed it will not be possible to quantify such effects, as it is not inconceivable that natural annual differences in the size structure of the juvenile striped bass population (Austin & Hickey 1978) are causing or contributing to the observed variation.

Agreement between the results of the Virginia trawl and seine indices of juvenile striped bass abundance must be considered weak at best. While the overall annual indices were significantly ($P<0.004$) positively correlated, the relationship was not strong ($r^2=0.57$, Fig. 12) and, for the most part, not substantiated by the results within river systems. As was the case with the seine surveys, there were large differences in inter-annual trends in index values between river

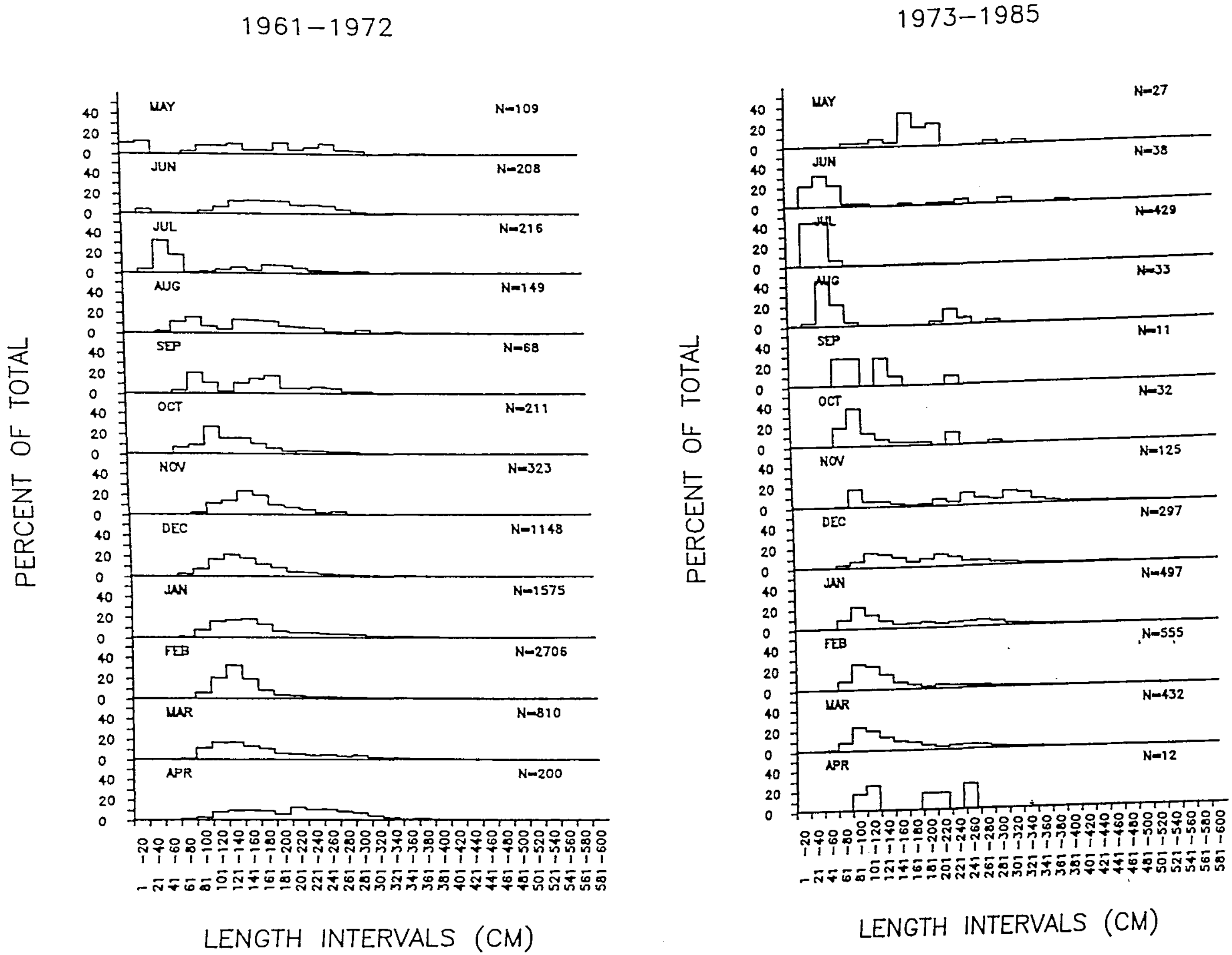

Figure 11. Composite monthly length frequencies for striped bass taken during the VIMS trawl surveys, 1961-1972 (unlined net) and 1973-1985 (lined net).

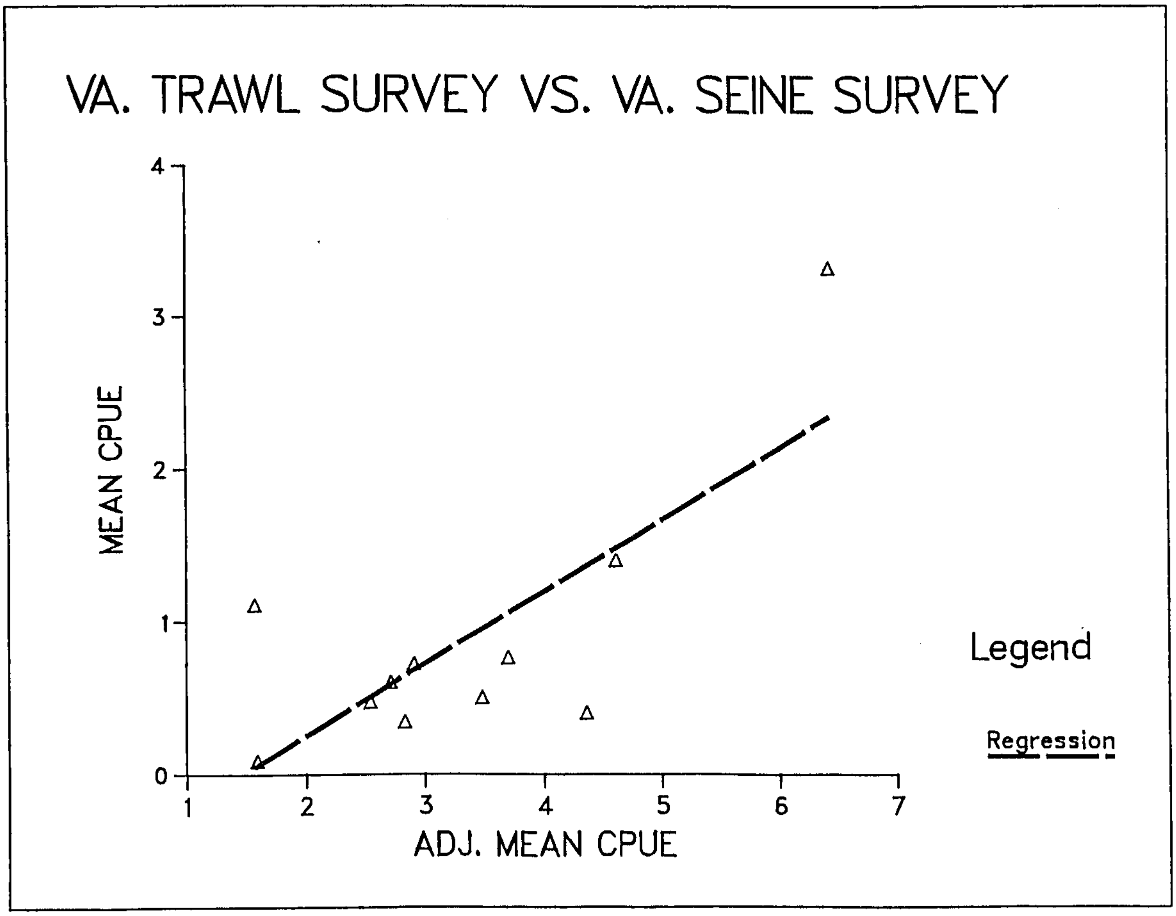

Figure 12. Annual striped bass juvenile index for the Virginia trawl survey (vertical axis) regressed against that for the Virginia seine survey (horizontal axis), 1967-73 and 1980-84 ($r^2 = 0.57$, $p < 0.004$).

systems (Fig. 13), but within-river comparisons of the trawl and seine indices yielded a significant correlation only for the James system and a <u>negative</u> (albeit insignificant) relationship for the York system (Fig. 14). Partitioning the trawl data set according to the use of lined or unlined trawl yields no improvement to these results.

Since within-river system populations of age-zero striped bass are geographically isolated, there is no reason that indices calculated across systems should show better agreement than within systems. As in the comparison between the two seine surveys, the correlation between the combined Virginia seine and trawl indices is strongly dependent on coincident high values during 1970, when relatively high values were recorded in all three systems during both surveys. In the absence of this well documented, exceptional yearclass throughout the Chesapeake Bay the combined indices would show little agreement.

It is evident that the trawl survey derived index does not provide the hoped for validation of the Virginia seine survey index. In view of the numerous sampling changes and undirected nature of the trawl surveys, the relatively short common time series, and the small sample sizes involved when making within-river comparisons (generally less than 30 samples per river per year per survey), this lack of agreement certainly does not invalidate the results of the seine surveys, but does raise serious questions as to the source of disagreement. The discrepancies may solely be the result of moderately high sampling variability in the seine survey coupled with very high sampling variability and gear/sampling design induced biases in the trawl data, but in view of the large natural fluctuations in striped bass yearclass strength even very crude measurements of

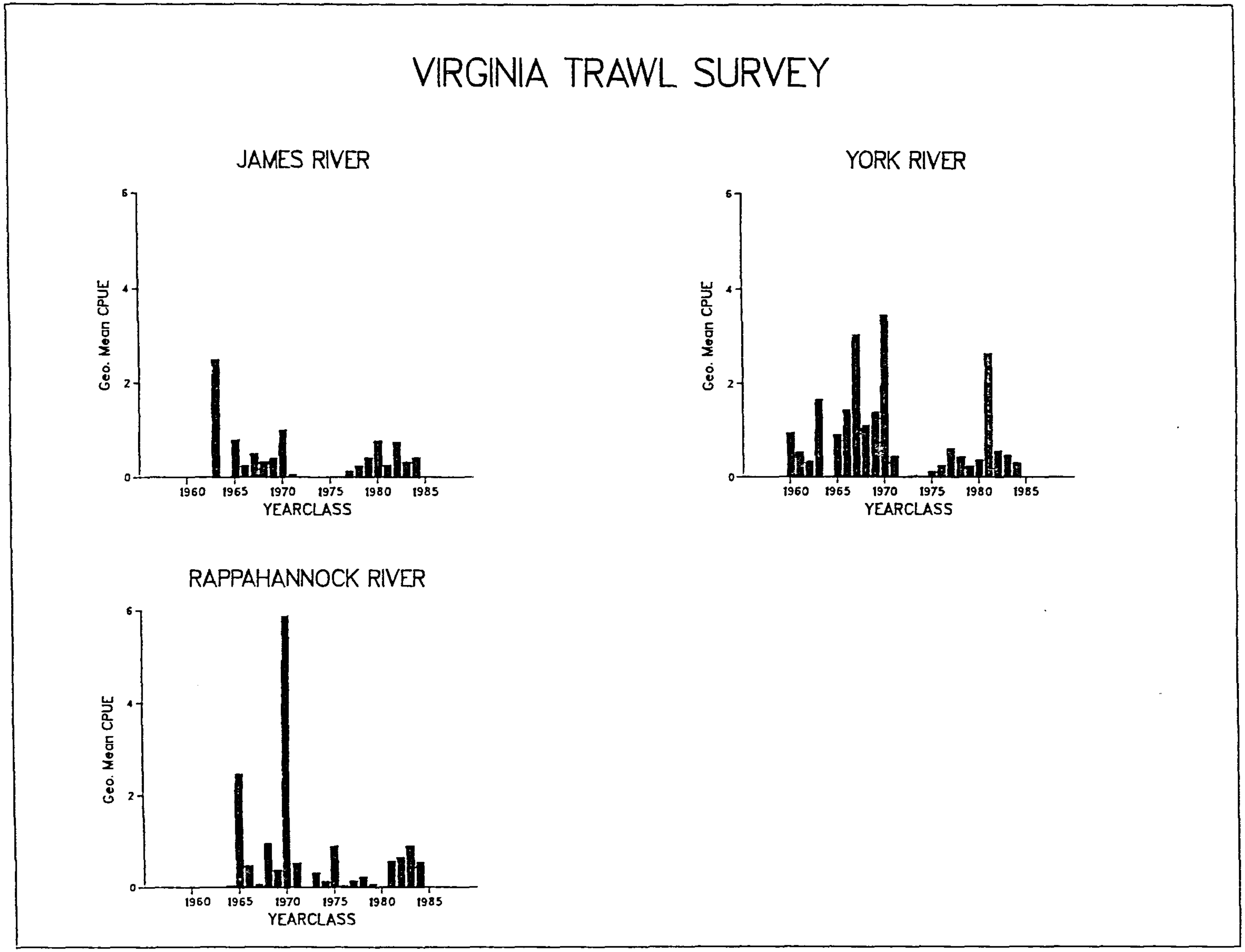

Figure 13. Annual geometric mean catch per tow of young-of-year striped bass taken on the primary overwintering grounds during the VIMS trawl surveys, 1961-85, broken down by drainage.

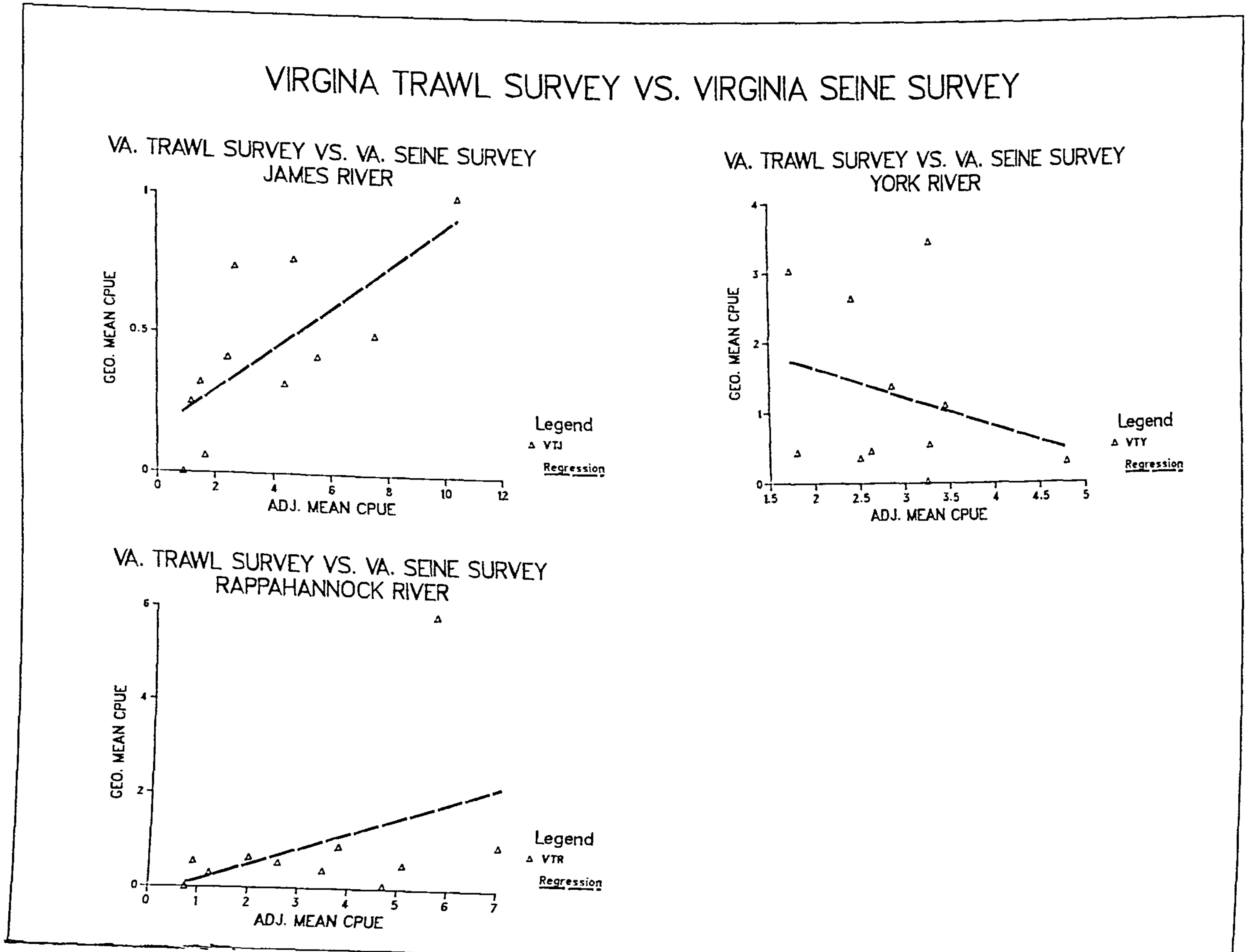

Figure 14. Annual striped bass juvenile index for the Virginia trawl survey (verical axis) regressed against that for the Virginia seine survey (horizontal axis), 1967-73 and 1980-85, for the James ($r^2 = 0.54$, $p < 0.005$), York ($r^2 = 0.08$, $p < 0.193$), and Rappahannock ($r^2 = 0.19$, $p < 0.093$) river systems.

relative abundance might be intuitively expected to show better agreement than was evidenced.

The Maryland seine survey and Virginia trawl surveys show essentially no agreement outside of maximal values in 1970, despite sharing a long time series (Fig. 15). Again, partitioning the trawl data set by gear differences effects no improvement. This nearly complete lack of agreement over such a long period would suggest that either striped bass recruitment success in the northern and southern portions of the Chesapeake Bay is indeed independent, or that at least one of the surveys is simply not providing a valid measure of recruitment. In view of the facts that the Virginia and Maryland seine surveys employ essentially the same sampling design, that the Maryland index has been correlated against subsequent landings data by Goodyear, and that the Virginia trawl and seine indexes show poor agreement, it is logical to again conclude that the previously mentioned problems inherent in the trawl survey may be largely responsible for these differences.

Prior to simply dismissing the trawl index as a viable measure of striped bass recruitment, multiple regression techniques were used in an attempt to evaluate the utility of this index to predict subsequent landings. Using the same approach as Goodyear (1985), total annual landings were regressed against the juvenile indices for the prior six years. Because of closures of the fishery in the James River in conjunction with Kepone contamination and the different years of sampling commencement in the three river systems, it was not possible to perform this analysis for the composite data set. The regressions were therefore performed on a system by system basis, with the James being excluded due the short and broken time series of valid landings

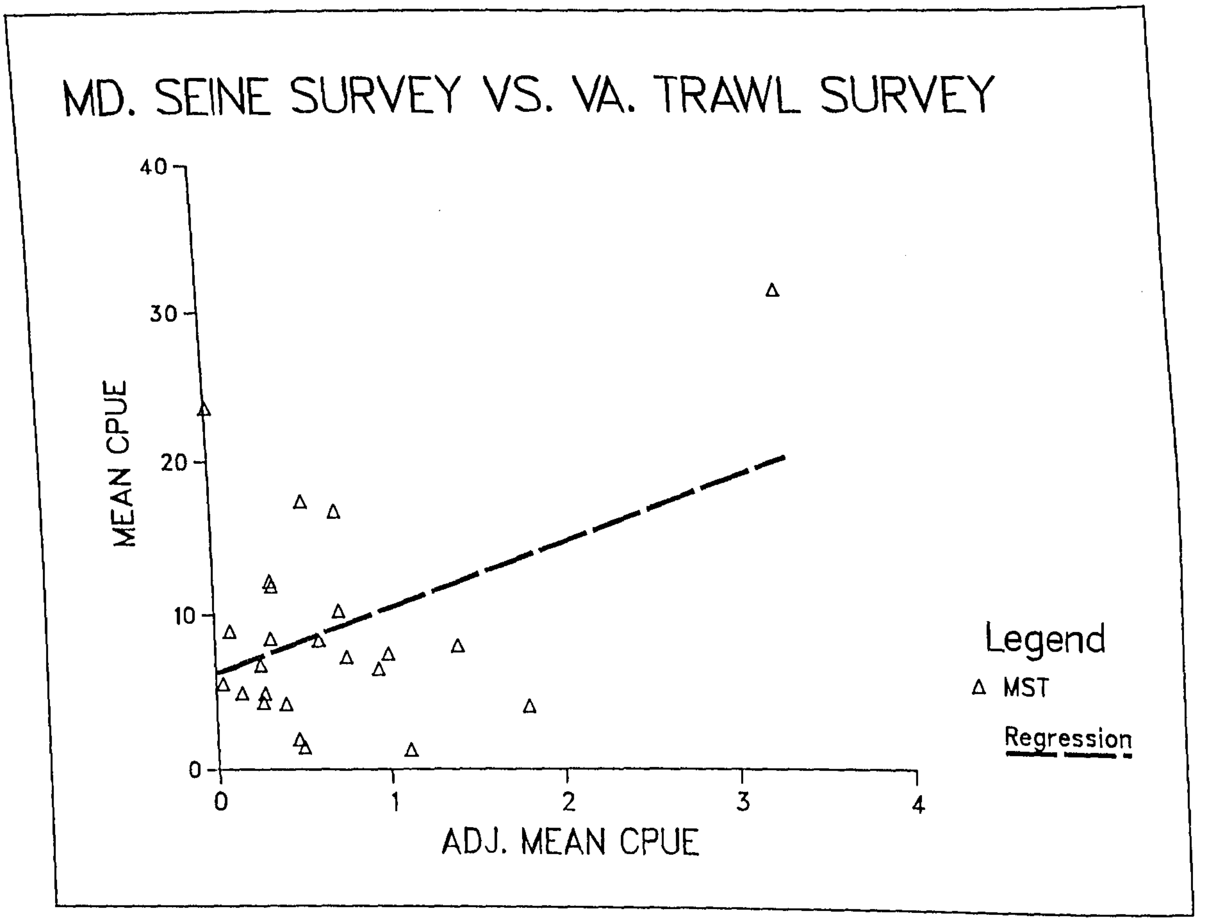

Figure 15. Annual striped bass juvenile index for the Maryland seine survey (vertical axis) regressed against that for the Virginia trawl survey (horizontal axis), 1960-1984 ($r^2 = 0.17$, $p < 0.021$).

data. Because each index value is lagged against the landings of several different years, the absence of index values for the 1972 yearclass posed a potentially severe reduction in the data sets. To avoid this problem, various estimated values across the observed range of values were iteratively substituted.

The results of the multiple regression analysis for the two systems examined (York and Rappahannock) were diametrically opposite. Irregardless of what value was substituted for the 1972 yearclass index, the fitted equations for the York River showed very low ($r^2<0.1$) and insignificant ($p>0.2$) correlation with the landings data for that system (supplied by the Virginia Marine Resources Commission, Table 2). In contrast, for the Rappahannock River all substituted values for 1972 resulted in fitted equations with highly significant ($p<0.01$) correlations which exhibited good fit ($r^2>0.75$) to the landings data. Substitution of the mean index value for this system (0.81) for 1972 resulted in an r^2 of 0.94. It is highly likely from all available evidence that the 1972 yearclass in the Rappahannock was of below average size. In addition to a very low index being recorded during the seine survey, additional trawl data collected in the Rappahannock during early 1973 (but not included in the present data set) also strongly indicated very poor recruitment in 1972, possibly a result of flood conditions resulting from the passage of Hurricane Agnes (Merriner and Hoagman 1973). All substitutions of below average values for 1972 resulted in an r^2 of greater than 0.91. The fitted equation and regression statistics for the run utilizing a 1972 value of 0.30 (a reasonable estimate based on the other available data) are given in Table 3. The regression coefficients reflect the fact that the overall fit is strongly dependent upon a relationship between

Table 2. Reported commercial landings of striped bass from the major Virginia Chesapeake Bay tributaries. Data from the Virginia Marine Resources Commission.

	Landings (thousands of pounds)		
Year	James	York	Rappahannock
1963	705	259	342
1964	400	158	190
1965	322	249	222
1966	736	399	465
1967	232	97	107
1968	203	148	153
1969	308	153	270
1970	116	58	91
1971	104	85	143
1972	64	91	159
1973	55	120	334
1974	24	83	762
1975	11	48	264
1976	0	128	150
1977	0	23	215
1978	6	11	95
1979	27	19	117
1980	9	6	80
1981	2	6	40
1982	5	17	19
1983	3	2	28

Table 3. Correlations among variables and multiple regression equation parameters of juvenile striped bass trawl index on landings for the Rappahannock River, 1964-80.

	Landings	Age 2	Age 3	Age 4
Age 2	-0.022 0.937			r signif.
Age 3	0.274 0.323	-0.034 0.906		
Age 4	0.887 0.000	-0.002 0.995	-0.048 0.865	
Age 5	0.097 0.732	-0.092 0.744	0.001 0.998	-0.108 0.702

Equation Parameters and Analysis of Variance

Multiple R	0.96208
R Square	0.92560
Adjusted R Square	0.90531
Standard Error	56.91717

	DF	Sum of Squares	Mean Square
Regression	3	443336.53	147778.84
Residual	11	35635.21	3239.56

F = 45.61689 Significance of F = 0.0000

Regression Coefficients

Variable	B	Std. Err. B	95% Confidence Interval of B	Beta	F	Sig. F
Age 4	112.70	10.11	90.45 - 134.94	0.924	124.35	0.000
Age 3	40.27	10.42	17.35 - 63.20	0.318	14.94	0.003
Age 5	23.88	10.09	1.68 - 46.08	0.196	5.60	0.038
(Constant)	39.74	20.97	-6.41 - 85.88		3.59	0.085

landings and the juvenile index from four years previous . This is in sharp contrast to the results of studies of the age composition of the commercial catch (Grant 1974; Loesch and Kriete 1982, 1983, 1984), which have shown the catches to be comprised primarily of younger fish. The strong simple correlation (r^2=0.78) between landings data and the index of four years previous is, however, largely dependent upon a single point, the sharp peak in the juvenile index in 1970 followed by the peak in landings in 1974. Although no sampling of the commercial catch was done in 1974, sampling of the commercial catch in the Rappahannock done in 1972-73 (Merriner and Hoagman, 1973) indicated that the exceptionally large 1970 yearclass had dominated the landings as three year olds to an overwhelming degree not seen with any other yearclass. It is not inconceivable that this yearclass also made a substantial and unique contribution to the landings as four year olds. If the 1974 data is excluded from the multiple regression, the regression coefficient for the juvenile index three years previous becomes the largest, in agreement with the results of Goodyear (1985).

It is very difficult to understand why the trawl survey index should provide an apparently good predictor of future landings in one river system and show no such relationship at all in another. There are many factors which can influence the accuracy of both the estimates of the juvenile index value (environmental effects on distribution, sampling artifacts, etc.) and landings data (gear selectivity, differential effort, inconsistencies in reporting, etc.) and the relationship between them (differential mortality, exchange between rivers). Commercial fishing efforts in the York system have traditionally been less organized and consistent than those in the

Rappahannock, but there is little reason to expect the net effects to be so different between river systems.

It is noteworthy that the York system was the system which showed by far the poorest agreement between the seine and trawl derived indices, as well as no relationship between the trawl index and landings data. It is possible that because the upper portion of the York system is bifurcated into the Pamunkey and Mattaponi rivers, but trawl sampling in the upper reaches took place almost exclusively within the Pamunkey tributary, an additional source of error was introduced. The largest trawl catches were taken in the uppermost portion of the mainstem York and the adjacent lower reaches of the Pamunkey. Data taken during the seine survey indicates strongly that annual recruitment rates in the two tributaries may be largely unrelated (Colvocoresses 1983, 1984). There may have been significant overwintering populations of young-of-year striped bass in the lower Mattaponi which were not sampled during the trawl surveys but which did exert substantial effects on subsequent landings.

From the present data sets it is not possible to evaluate which of the two Virginia data sets (trawl or seine) provides a better measure of striped bass recruitment. The multiple regressions of index values on subsequent landings (both in the present study and by Goodyear) indicate that both methodologies have the potential for providing a valid measure of relative annual striped bass recruitment, but the poor agreement between indices generated by the two Virginia surveys, the inability to validate the York River trawl indices against subsequent landings, and the large estimation errors associated with both techniques demonstrate that this potential is not always realized (at least at the present levels of sampling effort).

Both techniques have strong advantages and disadvantages. The seine surveys are extremely economical and logistically simple to perform, but due to the limited amount of suitable and available sampling sites, are restricted to a fixed station sampling design and therefore subject to inherent sampling biases. The trawl surveys can and have been conducted with a random sampling design, but adequate random sampling of multiple large river systems has proven extremely expensive and labor intensive, to the extent that sampling periodicity was restricted to semi-annually even when conducted under the joint auspices of several large research programs.

A possible alternative approach would be the development of a directed small vessel/small trawl survey to be conducted in the same time frame and habitat as the seine surveys; i.e. during the summer months when juveniles are concentrated in shallow waters in the upper reaches of the river systems. During August and September of 1978 simultaneous multiple gear sampling aimed at evaluation of habitat utilization of young-of-year alosine fishes was conducted in the upper portions of each of the three river systems. Concurrent tows were made using a 30′ lined trawl towed along the channel bottom, a 5′ x 5′ Cobb trawl fished in midwater over the channel, a 16′ lined trawl towed from an outboard launch in waters of 6′ or less, and a pushnet (a 5′ x 5′ Cobb trawl modified for surface sampling while mounted on a frame ahead of a small vessel) at randomly chosen sites throughout the alosid (and coincidently the striped bass) nursery areas. The highest catch rates of young-of-year striped bass were observed with the small trawl fished in shallow water (Fig. 16), while the only comparable catches were taken by the much larger 30′ net fished in deeper water. The overall catch-per-effort of even the more successful 16′ trawl

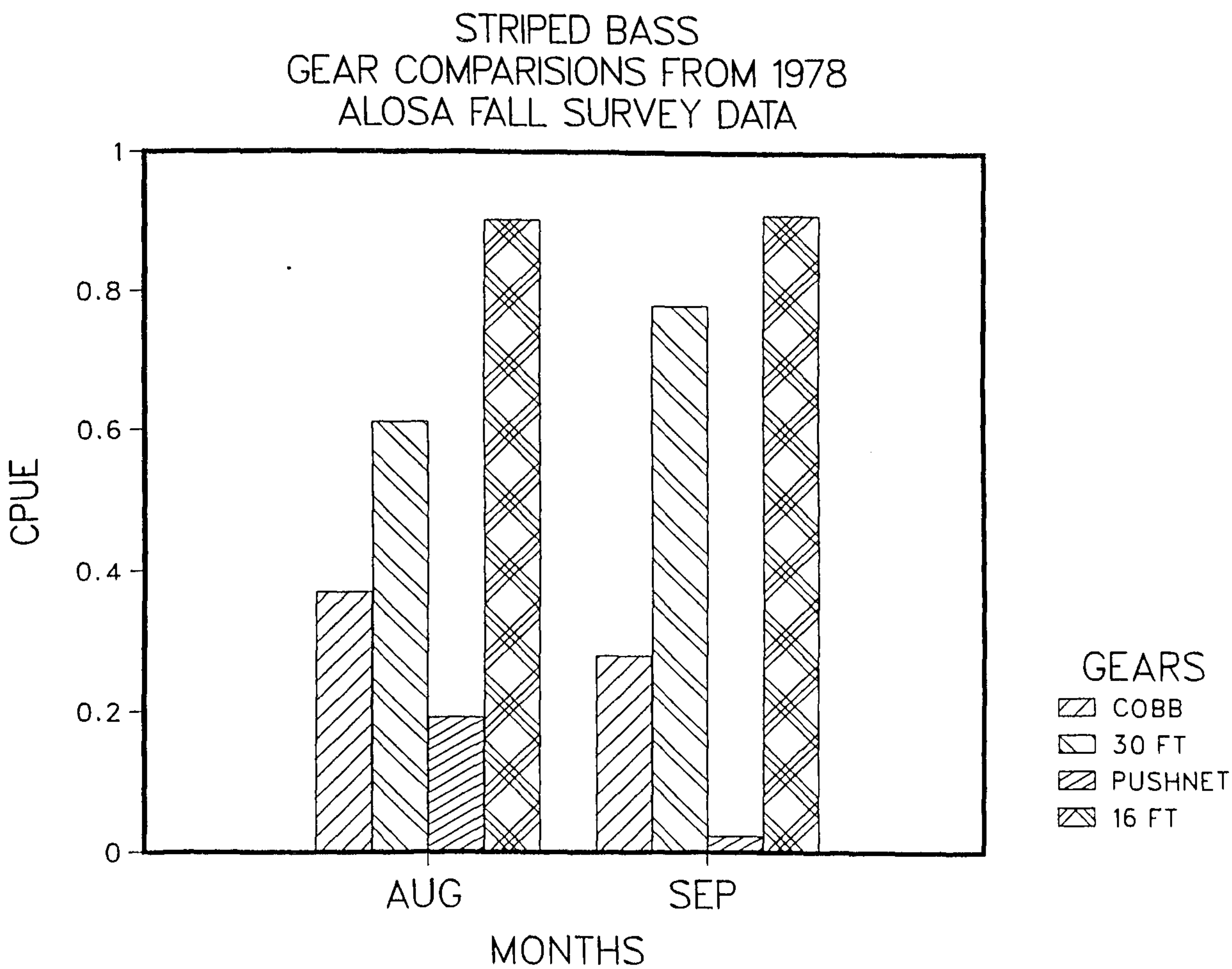

Figure 16. Mean catch per 5 min. tow by sampling gear of striped bass taken during 1978 VIMS comparison studies.

was, however, quite low (<1 fish per 5 min. tow). This may be simply a reflection of a weak 1978 yearclass (as was suggested by the trawl survey), rather than a reflection of low sampling efficiency. Trawl sampling of a limited area from an economical outboard vessel could conceivably provide a feasible means of conducting a randomized, directed annual survey of young-of-year striped bass abundance, but further field sampling will be required to investigate this possibility (and is being conducted concurrently with this project).

Relationships to Environmental Parameters

Characterization of the influence of major environmental parameters on each of the three surveys was undertaken in order to determine if either interannual or interregional differences in environmental conditions may be exerting general effects on the distribution or survival of juvenile striped bass, contributing either to the inconsistent results seen between the surveys or to the high variability seen within each survey. Of particular interest is whether there are significant differences in the general environmental conditions encountered on the Maryland and Virginia nursery grounds which could lead to differential results in estimating yearclass strength while using essentially the same sampling methodology.

Previous analyses of the effects of environmental parameters on the Virginia seine survey results (Dias 1982; Colvocoresses 1983, 1984, 1985) have shown relationships between survey results and sampling period, salinity, water temperature and drainage. Catch rates are usually maximal in July at the commencement of sampling and steadily decline as the sampling season progresses (Table 4a),

Table 4a. Catch of young-of-year striped bass per seine haul taken in the Virginia seine survey summarized by month.

Month	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
July	1402	1.08	0.993	4.46	3.77-5.23	336
August	913	0.82	0.877	2.89	2.41-3.42	321
September	719	0.57	0.794	1.75	1.45-2.08	415
	3034	0.81	0.907	2.83	2.55-3.12	1072

Table 4b. Catch of young-of-year striped bass per seine haul taken in the Maryland seine survey summarized by month.

Month	Total	Mean	Std. Dev.	C.I. (± 2 SE)	N
July	5175	10.87	21.459	8.91-12.8	476
August	4382	8.38	17.009	6.89-9.87	523
September	3512	6.88	18.323	5.27-8.51	510
	13069	8.66	19.004	7.68-9.64	1509

presumably a reflection of juvenile mortality coupled with increasing gear avoidance ability with growth. The results of the Maryland survey have also demonstrated this pattern (Table 4b), but the proportional decrease between the July and September sampling periods was considerably less. This could be a reflection of any number of causes, such as higher mortality rates on the Virginia nursery grounds, a tendency for juveniles to depart the shallows earlier in the lower portion of the Bay or possible effects of the apparently higher average densities of juveniles in the Maryland nursery zone on sampling efficiency or seasonality of distribution.

Water temperatures undoubtedly affect the distribution of juvenile striped bass (particularly late in the sampling season), but the distribution of catch rates with respect to temperature show high variation and no evident pattern for either survey (Tables 5a & 5b). This is not surprising inasmuch as the seasonal cycle of water temperatures peaks during the middle of the sampling period, whereas catch rates are steadily declining. Intermediate water temperatures may be encountered either during the earliest portion of the sampling period when average catch rates are highest, or during September when they are lowest. Low water temperatures which might be expected to exert strong effects on distribution are not encountered during the temporally restricted survey period.

The distribution of catch rates with respect to salinity show similar trends between the two surveys but, as was the case with the monthly trend, a smaller magnitude of difference within the Maryland

Table 5a. Catch of young-of-year striped bass per seine haul taken in the Virginia seine survey summarized by water temperature.

Temp. (deg. C)	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
15-19.9	79	1.01	0.908	4.00	2.05-6.82	24
20-24.9	335	0.55	0.741	1.67	1.30-2.08	227
25-29.9	1693	0.87	0.924	3.17	2.75-3.61	547
30-34.9	814	1.01	0.989	3.95	3.14-4.88	202
	2921	0.83	0.912	2.94	2.64-3.25	1000

Table 5b. Catch of young-of-year striped bass per seine haul taken in the Maryland seine survey summarized by water temperature.

Temp. (deg. C)	Total	Mean	Std. Dev.	C.I. (± 2 SE)	N
15-19.9	179	7.76	12.707	2.36-13.1	24
20-24.9	1747	7.34	15.243	5.37-9.32	238
25-29.9	8754	9.91	21.925	8.44-11.4	883
30-34.9	1049	7.95	14.861	5.36-10.5	132
	11729	9.19	20.060	8.01-10.3	1276

survey results. Highest catch rates were encountered in the freshest portion of the nursery areas and lowest rates recorded in the most saline reaches in both states (Tables 6a & 6b), but proportionately greater numbers of juveniles were taken at intermediate salinities during the Maryland survey. This may again be the result of higher densities of individuals on the northern nursery areas. The dominant yearclass of 1970 was much more widely distributed throughout the estuarine reaches of the Virginia tributaries than other, smaller yearclasses (Burton & Dias 1981).

While very different trends have been seen in the recruitment indices of the three Virginia river systems, the overall average catch rates have been quite similar (Table 7a). This is in sharp contrast to the cumulative results of the Maryland seine survey where one system, the Upper Bay, has an overall average catch rate about twice that seen in the other three systems (Table 7b). The Upper Bay is a physiographically unique sampling unit, consisting of stations located in or near the mouths of several small, primarily freshwater river systems as opposed to a linear array of stations arranged along the axis of a single major river system with a pronounced and variable salinity gradient. The higher historical average catch rates seen in the Upper Bay are probably a reflection of both higher densities of juveniles and the absence of stations located in less preferred higher salinity regimes. The differences in salinity regimes between the Upper Bay and the gradient river systems are not sufficient to account for the magnitude of difference observed, particularly since catch rates were significantly lower only at salinities exceeding 15 ppt., which were rarely encountered in any system (Table 6b).

Environmental variables associated with the trawl survey index

Table 6a. Catch of young-of-year striped bass per seine haul taken in the Virginia seine survey summarized by salinity.

Salinity (ppt.)	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
0-4.9	2635	0.87	0.922	3.16	2.83-3.51	863
5-9.9	296	0.61	0.860	1.91	1.31-2.61	124
10-14.9	77	0.47	0.668	1.38	0.81-2.05	63
15-19.9	2	0.13	0.280	0.31	-0.10-0.78	11
	3010	0.81	0.907	2.83	2.56-3.13	1061

Table 6b. Catch of young-of-year striped bass per seine haul taken in the Maryland seine survey summarized by salinity.

Salinity (ppt.)	Total	Mean	Std. Dev.	C.I. (± 2 SE)	N
0-4.9	7696	10.09	19.653	8.68-11.6	762
5-9.9	2235	7.21	16.915	5.29-9.13	310
10-14.9	1482	9.81	27.326	5.37-14.2	151
15-19.9	18	2.57	3.564	-0.12-5.27	7
	11431	9.29	20.102	8.15-10.4	1230

Table 7a. Catch of young-of-year striped bass per seine haul taken in the Virginia seine survey summarized by drainage and river.

Drainage River	Total	Mean ln(x+1)	Std. Dev.	Adjust. Mean	C.I. (± 2 SE)	N
James Drainage	1290	0.85	1.042	3.07	2.50-3.70	347
James	515	0.78	0.739	2.69	1.39-4.43	237
Chickahominy	775	1.37	1.184	6.66	4.85-8.92	110
York Drainage	902	0.80	0.821	2.80	2.39-3.25	374
Mattaponi	439	0.74	0.763	2.48	2.02-3.00	220
Pamunkey	463	0.89	0.893	3.30	2.55-4.16	154
Rappahannock Dr.	842	0.77	0.851	2.63	2.20-3.09	351
	3034	0.81	0.907	2.83	2.55-3.12	1072

Table 7b. Catch of young-of-year striped bass per seine haul taken in the Maryland seine survey summarized by drainage.

Drainage	Total	Mean	Std. Dev.	C.I. (± 2 SE)	N
Upper Bay	6384	13.63	23.980	11.4-15.8	483
Potomac	2919	6.12	15.245	4.72-7.52	477
Choptank	2121	7.68	19.823	5.93-10.1	276
Nanticoke	1445	5.29	10.532	4.02-6.57	273
	13069	8.66	19.004	7.68-9.64	1509

are not directly comparable to those collected with the seine surveys, both because of the different seasonal timing of the collections and the added dimensionality (depth) of the sampling scheme. Catch rates during the winter trawl surveys did not show the regular decline through the sampling season seen during the seine surveys (Table 8). As little or no growth occurs during this period (Fig. 11, Appendix 2), there is no reason to anticipate progressive net avoidance ability through the sampling period, but it is difficult to assess whether the relatively constant catch rates across sampling periods (months) imply negligible natural mortality. There was a distinct inverse relationship between catch rates and water temperatures (Table 9), suggesting a very plausible concentration of individuals in the channel areas sampled during colder periods, and possibly increased vulnerability to capture at lower temperatures. This would be compatible with the peak in catch rates seen in February. There is, however, apparently no general trend for first year striped bass to seek the deepest and ostensibly warmest waters within the channels during the winter months. Average catch rates also showed an inverse relationship to sampling depth within the depth range included (Table 10), although striped bass juveniles were only rarely taken at shallower depths (< 5 meters) during this season.

Distribution of winter catches with respect to salinity showed a very different pattern from that seen during the summer. Lowest average catch rates were encountered in the brackish waters so highly favored during the earlier summer seine season (Table 11). Catch rates were relatively even at higher salinities up to about 20 ppt., after which they declined again. The distributions of temperature, depth and salinity were interrelated to such an extent that it is not

Table 8. Catch of young-of-year striped bass per 5 min. tow taken in the Virginia trawl survey summarized by month.

Month	Total	Mean ln(x+1)	Std. Dev.	Geomet. Mean	C.I. (± 2 SE)	N
January	845	0.37	0.745	0.45	0.36-0.54	569
Feburary	1349	0.44	0.829	0.55	0.44-0.67	488
March	506	0.36	0.715	0.43	0.33-0.53	415
	2700	0.39	0.766	0.47	0.42-0.54	1472

Table 9. Catch of young-of-year striped bass per 5 min. tow taken in the Virginia trawl survey summarized by water temperature.

Temp. (deg. C)	Total	Mean ln(x+1)	Std. Dev.	Geomet. Mean	C.I. (± 2 SE)	N
0-2.4	1141	0.61	1.052	0.84	0.59-1.13	203
2.5-4.9	774	0.48	0.800	0.62	0.50-0.75	438
5-7.4	402	0.33	0.710	0.39	0.28-0.50	316
7.5-9.9	140	0.27	0.592	0.31	0.19-0.43	170
10-12.4	14	0.15	0.372	0.16	0.05-0.29	51
	2471	0.42	0.797	0.52	0.45-0.59	1178

Table 10. Catch of young-of-year striped bass per 5 min. tow taken in the Virginia trawl survey summarized by depth of tow.

Depth (meters)	Total	Mean ln(x+1)	Std. Dev.	Geomet. Mean	C.I. (± 2 SE)	N
5-9.9	2058	0.43	0.808	0.54	0.46-0.62	1018
10-14.9	579	0.32	0.701	0.38	0.28-0.49	332
15-19.9	47	0.22	0.481	0.25	0.13-0.38	95
20-24.9	10	0.17	0.527	0.19	-0.06-0.51	61
25-29.9	6	0.28	0.753	0.33	-0.25-1.35	7
	2700	0.39	0.766	0.47	0.42-0.54	1472

Table 11. Catch of young-of-year striped bass per 5 min. tow taken in the Virginia trawl survey summarized by salintiy.

Salinity (ppt.)	Total	Mean ln(x+1)	Std. Dev.	Geomet. Mean	C.I. (± 2 SE)	N
0-4.9	212	0.19	0.478	0.21	0.16-0.27	447
5-9.9	402	0.63	0.865	0.88	0.65-1.15	170
10-14.9	1208	0.63	1.022	0.87	0.66-1.11	297
15-19.9	669	0.51	0.875	0.66	0.48-0.87	222
20-24.9	27	0.23	0.444	0.26	0.13-0.42	61
	2518	0.42	0.800	0.53	0.46-0.60	1197

possible to assess the relative influences of each on the winter distribution of striped bass juveniles from this data set. Within a given sampling period, all three variables tended to increase in the downstream direction (since the channels shoal in the upriver portions of the study area and lower bottom temperatures occur in shallower waters). All three factors undoubtedly play important roles in determining juvenile striped bass winter distribution, but temperature is by far the most variable factor, both between and within years, and will exert the greatest environmental effect on index values. The fact that the greatest average catch rates were observed in the shallower depth interval point strongly to the presence of juveniles in the shoaler portions of the channels not sampled during the extensive portions of the data set which involved only mid-channel stations. The degree of concentration in mid-channel is undoubtedly strongly related to water temperatures and probably varies considerably from winter to winter, with greatest concentration occurring during the most severe winters.

Overall average catch rates in the James River drainage were significantly lower than those seen in the other two systems (Table 12), as opposed to the even averages seen during the seine survey. In terms of breadth within the sampling area, the James is the largest of the three systems sampled. Therefore the lower average catches may be a result of diluting a population recruited from equivalent amounts of shoreline nursery areas into a greater open water area. The Rappahannock, which displayed the intermediate mean catch value, also is intermediate in size of the sampling area, but the fact that the highest rate was encountered in the York may be related the bifurcated nursery zone, as well as to concentration factors.

Table 12. Catch of young-of-year striped bass per 5 min. tow taken in the Virginia trawl survey summarized by drainage .

Drainage	Total	Mean ln(x+1)	Std. Dev.	Geomet. Mean	C.I. (± 2 SE)	N
James	310	0.35	0.558	0.28	0.22-0.35	461
York	1298	0.52	0.817	0.62	0.52-0.73	652
Rappahannock	1092	0.40	0.871	0.49	0.36-0.64	359
	2700	0.39	0.766	0.47	0.42-0.54	1472

Multiple regression techniques were applied to the Maryland seine survey and Virginia trawl survey in an attempt to evaluate the relative importance of the environmental variables discussed above and to examine the possibility of interactive effects, using the same approach as had been previously utilized with the Virginia seine data (Dias 1982, Colvocoresses 1983). First stage equations (i.e. those in which catch rates were regressed against the environmental variable set without allowing squared or interaction terms to enter the equations) resulted in highly significant ($P < 0.001$) but very weak ($r^2 < 0.15$) equations which are of little use in assessing the relative importance of the environmental variables entered. The high degree of multicolinearity among the original independent variables discussed above, in addition to compromising the already weak results of the first stage equations, produced confused patterns and no improvement in results or indications of evident non-trivial interactions in second stage equations. It is evident that the distribution and abundance of juvenile striped bass, while undoubtedly affected by the gross environmental variables recorded during these surveys, are more strongly shaped by unmeasured environmental and biological factors occurring on the nursery grounds during the survey period as well as these same unmeasured and measured factors operating on the populations prior to the sampling period.

CONCLUSIONS AND RECOMMENDATIONS

While the observed inconsistencies in the relative annual beach seine generated indices of juvenile striped bass abundance in the Maryland and Virginia portions of Chesapeake Bay appear to be at least in part attributable to real differences in recruitment success, it is evident from the present study that the associated high sampling variability (both natural and artifactual) prevents valid comparisons between the two surveys (or between drainages within surveys) except in years of very high or very low yearclass strengths. Although Goodyear's (1985) demonstration of a relationship between the Maryland seine index and subsequent landings has been largely construed as validating the accuracy of that index, it should be noted that even a very imprecise measure of stock abundance will provide a useful relative index value if the variation in true stock size is proportionally very large. In the case of the mean annual Maryland juvenile striped bass index, there has been a twenty-five fold variation in recorded values. Assuming actual abundances have varied on approximately the same scale, the seeming inconsistency between the very low sampling precision observed here and by Heimbuch et al. (1983) and the high correlations with landings found by Goodyear (1985) is reconcilable. Given very large fluctuations in yearclass strength, the smoothing effect of regressing multiple years of index data against landings, and a strong underlying trend in the time series (declines in landings and juvenile indices), a high degree of correlation is possible with only very roughly accurate measures of either variable.

It will not be possible to determine the degree to which overall recruitment success of striped bass in the upper and lower portions of Chesapeake Bay is interrelated until more precise measures of juvenile abundance are developed. The present data suggests that, with the exception of years such as 1970 (when for undetermined reasons relative recruitment was high Baywide), annual recruitment success is largely independent between drainages, but further research is needed to verify this observation. It is evident, however, that no particular segment of the Bay can be considered representative of the whole with respect to striped bass production. Ideally, all spawning/nursery areas within the Bay should be sampled and should contribute to a Baywide recruitment index in proportion to their importance in determining future stock size. Unfortunately proportional importance of specific areas may be presently undergoing significant historical changes, as witnessed by the dramatic declines in the Upper Bay sampling area.

The beach seine surveys presently being conducted in Maryland and Virginia to monitor striped bass recruitment success, while producing indices of very poor precision and some bias, are serving the purpose for which they were originally intended; that is, to provide a basis for monitoring long term trends and identifying dramatically high or low levels of annual recruitment. Because of it's exceptional time series length of consistent collections, the Maryland seine index series has understandably been used as the best available measure of historical recruitment. Unfortunately, this recent widespread use has often resulted in index values being interpreted in a much more quantitative sense than the sampling and statistical properties of the original data set justify, particularly when using indices for specific river drainages.

If measures of recruitment success are to continue to play a dominant role in future management strategies, much more quantitative and precise indices of juvenile abundance are highly desirable if not required. In principal, an index which varies directly or in a known manner to absolute recruitment success and which can be measured with reasonable precision within each system of the Bay should be the ultimate objective, but such a measure is well beyond the scope of present effort or knowledge. A much more thorough understanding of temporal and spatial juvenile distribution, causes and timing of first year mortality and possibly the development of a new sampling methodology will be required to achieve such an end. While this goal should continue to be actively pursued, best management of the stock would dictate as immediate improvement in measures of recruitment as is feasible.

In view of the current mandated use of the Maryland seine index in management regulations and the unique historical perspective offered by that data set, this project must be continued for the foreseeable future, and any immediate effort to create an improved Baywide measure of striped bass recruitment must of necessity be structured around it. An obvious first step in the creation of a Baywide recruitment index should be the standardization of seining methodology between the Maryland and Virginia surveys. Because of the longer time series, more consistent methodology, and mandated management uses of the Maryland index, the Virginia methodology should be changed to conform to that used in Maryland to the total extent possible without seriously compromising the Virginia historical time series. This should be possible by intercalibrating the two methodologies, an effort already underway with funding from the Chesapeake Bay Stock Assessment Committee.

Improvement of precision and reduction of sampling biases is a more complex matter in the face of limited available long-term funds and the need to maintain the integrity of historical continuity. The simplest approach to increasing precision is to increase sample size, which in the present situation can be accomplished by either adding stations or increasing sampling frequency at the presently occupied stations or a combination of both. Increasing the number of stations should reduce the overall bias associated with site selection, but may introduce a systematic bias between indices calculated from different station sets (a primary reason the auxiliary seine stations added during the Maryland seine survey are not included in the computation of the annual index). Changes in sampling schedule also have the potential for introducing bias.

Despite these complications, there can be little doubt that sample sizes should be increased. The coefficients of variation for the individual river systems are generally too high to permit meaningful comparisons between systems within years, but there is every indication that recruitment success is highly variable between drainages within years and should be adequately monitored at that level. Increasing sampling periodicity should inflict minimal bias as long as the overall sampling period remains the same. While the addition of new stations can indeed introduce systematic biases, these biases should be assessable (after an adequate time period) by comparison of results from the original and expanded station sets.

Effective sample size may be able to be increased without a completely commensurate increase in effort by eliminating replicate hauls in favor of more stations or more frequent sampling. Because the 'replicate' hauls are pulled over the same bottom after only a moderate time interval, they properly constitute only a single sample after pooling. Preliminary comparisons of replicate tows done during the Virginia surveys indicate that catches of juvenile striped bass are significantly less in the second or 'replicate' haul (averaging about 60% of the first catch). Annual recruitment indices calculated from samples taken in Virginia prior to the introduction of replicate tows are therefore probably producing higher (albeit more representative) density estimates than the more recent and Maryland indices, and should be adjusted as soon as a complete analysis can be performed. Sample sizes reported during periods of replicate sampling should also be corrected to reflect only pooled replicates.

Estimation errors associated with the Maryland index may be significantly reduced by applying an appropriate transformation prior to calculation of the index. The Virginia seine catch data have been shown to conform very strongly to a negative binomial distribution, and to be greatly normalized by logarithmic transformation, which also considerably reduced the coefficients of variation and confidence intervals about the means (Colvocoresses 1984).

Beyond immediate measures to standardize and expand the seine surveys, research directed at expanding the knowledge of the seasonal distribution and mortality of juvenile striped bass should be actively pursued. The seine surveys sample only a very limited type and portion of the total available habitat, and expansion of results collected there to unsampled areas and habitats is unjustified in absence of corroborative data. Open beachfronts are a proven well-frequented habitat of juvenile striped bass during their first summer, and there is significant evidence that yearclass strength is at least partially set prior to the survey period, but further sampling in other habitats and time frames will be required in order to determine if this is an optimal sampling strategy. At present the critical periods of natural mortality within the egg/larval/early juvenile phases which determine yearclass strength have not been established for even this well studied species. The most appropriate measures of recruitment seek to find an optimal solution to the problem of sampling too early, when significant periods of annually variable rates of mortality may not yet have occurred, and sampling too late, when growth and dispersion can lead to the inability to properly sample. Determination of such an optimal period for monitoring juvenile striped bass in the Chesapeake will require further careful study of all available data as well as substantially expanded field studies directed at this objective.

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Appendix Table 1. Mean catch per seine haul of young-of-year striped bass for the Maryland DNR beach seine survey summarized by year and sampling area. Adjusted coefficient of variation is based on combined annual mean and variance if sample size equaled that for a specfic sampling area.

Year	Sampling Area	Mean Catch	Std. Dev.	N	Coeff. of Var.	Adj. Coeff. of Var.
1958		17.34	16.019	19	0.212	
	Upper Bay	21.93	22.315	7	0.385	0.349
	Potomac	8.30	9.941	5	0.536	0.413
	Choptank	17.25	11.493	4	0.333	0.462
	Nanticoke	21.83	10.563	3	0.279	0.533
1959		1.24	2.417	19	0.448	
	Upper Bay	1.36	2.393	7	0.666	0.739
	Potomac	1.60	3.305	5	0.924	0.874
	Choptank	0.12	0.250	4	1.000	0.977
	Nanticoke	1.83	3.175	3	1.000	1.128
1960		6.45	8.646	19	0.308	
	Upper Bay	6.79	10.762	7	0.599	0.507
	Potomac	4.20	4.339	5	0.462	0.600
	Choptank	10.00	11.321	4	0.566	0.670
	Nanticoke	4.67	7.234	3	0.895	0.774
1961		17.34	28.152	22	0.346	
	Upper Bay	22.00	30.010	7	0.516	0.614
	Potomac	28.21	38.103	7	0.510	0.614
	Choptank	6.00	3.162	4	0.264	0.812
	Nanticoke	1.50	0.577	4	0.192	0.812
1962		12.10	18.448	44	0.230	
	Upper Bay	11.32	17.015	14	0.402	0.407
	Potomac	19.68	25.845	14	0.351	0.407
	Choptank	6.12	6.932	8	0.400	0.539
	Nanticoke	6.19	8.220	8	0.470	0.539
1963		4.05	6.287	44	0.234	
	Upper Bay	6.11	6.380	14	0.279	0.415
	Potomac	1.11	2.451	14	0.592	0.415
	Choptank	5.44	8.764	8	0.570	0.549
	Nanticoke	4.19	7.156	8	0.604	0.549
1964		23.50	35.741	44	0.229	
	Upper Bay	31.04	32.082	14	0.276	0.406
	Potomac	29.18	52.052	14	0.477	0.406
	Choptank	10.56	9.894	8	0.331	0.538
	Nanticoke	13.31	17.826	8	0.473	0.538

Appendix Table 1. (continued)

Year	Sampling Area	Mean Catch	Std. Dev.	N	Coeff. of Var.	Adj. Coeff. of Var.
1965		7.42	17.010	44	0.346	
	Upper Bay	2.14	5.044	14	0.629	0.613
	Potomac	3.36	7.164	14	0.570	0.613
	Choptank	9.50	15.083	8	0.561	0.810
	Nanticoke	21.69	32.877	8	0.536	0.810
1966		16.73	28.998	66	0.213	
	Upper Bay	32.40	44.045	21	0.297	0.378
	Potomac	10.52	13.650	21	0.283	0.378
	Choptank	13.67	18.230	12	0.385	0.500
	Nanticoke	3.25	4.429	12	0.393	0.500
1967		7.92	19.166	66	0.298	
	Upper Bay	17.38	31.774	21	0.399	0.528
	Potomac	1.90	2.468	21	0.283	0.528
	Choptank	5.25	6.451	12	0.355	0.699
	Nanticoke	4.54	4.693	12	0.298	0.699
1968		7.16	11.661	66	0.200	
	Upper Bay	13.07	17.048	21	0.285	0.355
	Potomac	0.74	1.211	21	0.358	0.355
	Choptank	6.25	5.817	12	0.269	0.470
	Nanticoke	8.96	9.416	12	0.303	0.470
1969		10.22	20.353	66	0.245	
	Upper Bay	25.67	30.410	21	0.259	0.435
	Potomac	0.21	0.514	21	0.523	0.435
	Choptank	4.75	4.535	12	0.276	0.575
	Nanticoke	6.17	6.939	12	0.325	0.575
1970		31.19	45.059	66	0.178	
	Upper Bay	35.48	49.283	21	0.303	0.315
	Potomac	20.10	18.315	21	0.199	0.315
	Choptank	57.21	72.370	12	0.365	0.417
	Nanticoke	17.08	22.546	12	0.381	0.417
1971		11.77	21.015	66	0.220	
	Upper Bay	23.71	27.540	21	0.253	0.390
	Potomac	8.52	19.416	21	0.497	0.390
	Choptank	6.25	10.378	12	0.479	0.516
	Nanticoke	2.04	2.942	12	0.416	0.516
1972		8.09	13.989	66	0.213	
	Upper Bay	12.14	19.625	21	0.353	0.377
	Potomac	1.86	3.034	21	0.356	0.377
	Choptank	11.04	12.585	12	0.329	0.499
	Nanticoke	8.96	12.850	12	0.414	0.499

Appendix Table 1. (continued)

Year	Sampling Area	Mean Catch	Std. Dev.	N	Coeff. of Var.	Adj. Coeff. of Var.
1973		8.86	19.090	66	0.265	
	Upper Bay	24.43	28.180	21	0.252	0.470
	Potomac	2.10	3.077	21	0.320	0.470
	Choptank	1.25	3.415	12	0.789	0.622
	Nanticoke	1.08	1.203	12	0.321	0.622
1974		5.55	9.546	66	0.212	
	Upper Bay	11.62	14.465	21	0.272	0.376
	Potomac	1.48	2.773	21	0.410	0.376
	Choptank	3.62	3.304	12	0.263	0.497
	Nanticoke	3.96	4.938	12	0.360	0.497
1975		6.67	9.650	66	0.178	
	Upper Bay	7.62	12.078	21	0.346	0.316
	Potomac	7.74	10.141	21	0.286	0.316
	Choptank	4.67	6.326	12	0.391	0.417
	Nanticoke	5.17	6.877	12	0.384	0.417
1976		4.91	13.277	66	0.333	
	Upper Bay	9.88	22.156	21	0.489	0.590
	Potomac	3.21	4.890	21	0.332	0.590
	Choptank	2.42	5.608	12	0.670	0.781
	Nanticoke	1.67	1.813	12	0.314	0.781
1977		4.86	10.068	66	0.255	
	Upper Bay	12.10	15.296	21	0.276	0.452
	Potomac	1.93	3.607	21	0.408	0.452
	Choptank	1.21	1.287	12	0.308	0.599
	Nanticoke	0.96	0.891	12	0.268	0.599
1978		8.45	10.509	66	0.153	
	Upper Bay	12.48	12.237	21	0.214	0.271
	Potomac	7.90	10.850	21	0.300	0.271
	Choptank	6.00	7.511	12	0.361	0.359
	Nanticoke	4.79	7.566	12	0.456	0.359
1979		4.30	7.477	66	0.214	
	Upper Bay	9.12	10.803	21	0.259	0.379
	Potomac	2.19	3.455	21	0.344	0.379
	Choptank	2.79	5.224	12	0.540	0.502
	Nanticoke	1.08	1.607	12	0.428	0.502
1980		1.92	3.070	66	0.196	
	Upper Bay	2.19	3.207	21	0.320	0.348
	Potomac	2.24	3.566	21	0.348	0.348
	Choptank	1.00	1.719	12	0.496	0.461
	Nanticoke	1.83	3.107	12	0.489	0.461

Appendix Table 1. (continued)

Year	Sampling Area	Mean Catch	Std. Dev.	N	Coeff. of Var.	Adj. Coeff. of Var.
1981		1.20	2.392	66	0.246	
	Upper Bay	0.29	0.717	21	0.548	0.436
	Potomac	1.38	2.706	21	0.428	0.436
	Choptank	1.29	1.251	12	0.280	0.577
	Nanticoke	2.37	3.850	12	0.468	0.577
1982		8.29	11.762	66	0.175	
	Upper Bay	5.52	6.566	21	0.259	0.310
	Potomac	10.02	16.352	21	0.356	0.310
	Choptank	12.17	12.483	12	0.296	0.410
	Nanticoke	6.21	7.460	12	0.347	0.410
1983		1.36	3.049	66	0.275	
	Upper Bay	1.21	2.250	21	0.404	0.488
	Potomac	1.98	4.766	21	0.526	0.488
	Choptank	0.87	0.856	12	0.282	0.645
	Nanticoke	1.04	1.602	12	0.444	0.645
1984		4.20	9.288	66	0.272	
	Upper Bay	6.10	12.017	21	0.430	0.482
	Potomac	4.67	11.037	21	0.516	0.482
	Choptank	2.83	1.838	12	0.187	0.638
	Nanticoke	1.46	2.210	12	0.437	0.638

Appendix Table 2. Log-transformed and adjusted mean catch per seine haul of young-of-year striped bass for the Virginia beach seine survey summarized by year and sampling area (adjusted mean = geometric mean x 2.28, the ratio of the overall arithmetic and geometric means). Adjusted coefficient of variation as in Appendix Table 1.

Year	Sampling Area	Mean Catch ln(x+1)	Std. Dev.	Adj. Mean	N	Coeff. of Var.	Adj. Coeff. of Var.
1967		1.11	0.993	4.61	53	0.123	
	James	1.47	1.080	7.60	17	0.179	0.218
	York	0.57	0.806	1.74	12	0.411	0.259
	Rappahannock	1.12	0.926	4.71	24	0.169	0.183
1968		0.96	0.906	3.70	66	0.116	
	James	0.50	0.801	1.50	21	0.346	0.205
	York	0.92	0.798	3.46	21	0.189	0.205
	Rappahannock	1.40	0.905	6.98	24	0.132	0.192
1969		0.82	0.908	2.91	77	0.126	
	James	0.73	1.024	2.45	28	0.265	0.208
	York	0.81	0.785	2.86	21	0.211	0.241
	Rappahannock	0.92	0.891	3.47	28	0.182	0.208
1970		1.34	1.115	6.42	77	0.095	
	James	1.73	1.251	10.58	28	0.137	0.157
	York	0.89	1.025	3.28	18	0.271	0.196
	Rappahannock	1.25	0.933	5.64	31	0.135	0.150
1971		0.81	0.847	2.83	80	0.117	
	James	0.55	0.880	1.67	27	0.308	0.202
	York	0.58	0.617	1.81	21	0.230	0.229
	Rappahannock	1.17	0.840	5.07	32	0.127	0.185
1972		0.42	0.588	1.19	116	0.130	
	James	0.27	0.521	0.70	26	0.384	0.275
	York	0.60	0.615	1.89	48	0.147	0.202
	Rappahannock	0.30	0.548	0.80	42	0.281	0.216
1973		0.53	0.790	1.59	84	0.163	
	James	0.33	0.676	0.89	24	0.417	0.304
	York	0.89	0.952	3.25	24	0.219	0.304
	Rappahannock	0.42	0.676	1.21	36	0.265	0.249
1980		0.75	0.901	2.54	89	0.128	
	James	1.13	1.032	4.77	30	0.167	0.220
	York	0.74	0.838	2.51	35	0.191	0.203
	Rappahannock	0.28	0.557	0.75	24	0.402	0.246

Appendix Table 2. (continued)

Year	Sampling Area	Mean Catch ln(x+1)	Std. Dev.	Adj. Mean	N	Coeff. of Var.	Adj. Coeff. of Var.
1981		0.52	0.691	1.57	116	0.123	
	James	0.42	0.748	1.20	38	0.286	0.215
	York	0.72	0.735	2.42	48	0.147	0.191
	Rappahannock	0.33	0.433	0.88	30	0.242	0.242
1982		0.78	0.968	2.71	106	0.120	
	James	0.78	1.075	2.71	36	0.229	0.206
	York	0.89	0.947	3.28	42	0.164	0.191
	Rappahannock	0.62	0.860	1.98	28	0.260	0.233
1983		0.93	0.832	3.48	102	0.089	
	James	1.08	0.952	4.43	36	0.147	0.150
	York	0.77	0.625	2.63	42	0.126	0.139
	Rappahannock	0.98	0.938	3.77	24	0.196	0.183
1984		1.07	1.009	4.36	106	0.092	
	James	1.24	1.158	5.59	36	0.156	0.157
	York	1.13	1.033	4.80	42	0.141	0.146
	Rappahannock	0.75	0.671	2.57	28	0.168	0.178
1985		0.72	0.859	2.41	142	0.100	
	James	0.83	0.914	2.94	48	0.159	0.172
	York	0.92	0.866	3.42	56	0.126	0.159
	Rappahannock	0.30	0.617	0.80	38	0.333	0.193

Appendix Table 3. Log-transformed and geometric mean catch per trawl tow of young-of-year striped bass for the Virginia trawl survey summarized by year and sampling area. Adjusted coefficient of variation as in Appendix Table 1.

Year-class	Sampling Area	Mean Catch ln(x+1)	Std. Dev.	Geo. Mean	N	Coeff. of Var.	Adj. Coeff. of Var.
1960		0.67	0.742	0.95	6	0.455	
	York	0.67	0.742	0.95	6	0.455	0.455
1961		0.43	0.557	0.54	11	0.390	
	York	0.43	0.557	0.54	11	0.390	0.390
1962		0.29	0.460	0.34	13	0.445	
	York	0.29	0.460	0.34	13	0.445	0.445
1963		1.03	1.001	1.80	26	0.190	
	James	1.25	0.169	2.49	5	0.060	0.434
	York	0.98	1.111	1.66	21	0.247	0.212
1964		0.01	0.081	0.01	40	0.998	
	James	0.00	0.000	0.00	14	0.000	0.000
	York	0.00	0.000	0.00	15	0.000	0.000
	Rappahannock	0.05	0.154	0.05	11	1.001	1.903
1965		0.70	0.940	1.01	48	0.195	
	James	0.59	0.835	0.80	20	0.318	0.302
	York	0.65	0.922	0.92	22	0.305	0.288
	Rappahannock	1.24	1.290	2.46	6	0.424	0.552
1966		0.55	0.876	0.73	48	0.231	
	James	0.22	0.278	0.25	17	0.309	0.388
	York	0.89	1.121	1.44	21	0.275	0.349
	Rappahannock	0.39	0.760	0.48	10	0.612	0.505
1967		0.88	1.095	1.41	35	0.211	
	James	0.41	0.585	0.51	13	0.395	0.346
	York	1.39	1.244	3.01	18	0.210	0.294
	Rappahannock	0.07	0.144	0.07	4	1.000	0.623
1968		0.57	0.798	0.77	53	0.192	
	James	0.28	0.433	0.32	18	0.362	0.330
	York	0.75	0.951	1.12	21	0.277	0.305
	Rappahannock	0.67	0.857	0.95	14	0.340	0.374
1969		0.54	0.790	0.72	49	0.207	
	James	0.35	0.480	0.42	17	0.336	0.352
	York	0.87	1.016	1.39	19	0.268	0.333
	Rappahannock	0.33	0.606	0.39	13	0.511	0.402

Appendix Table 3. (continued)

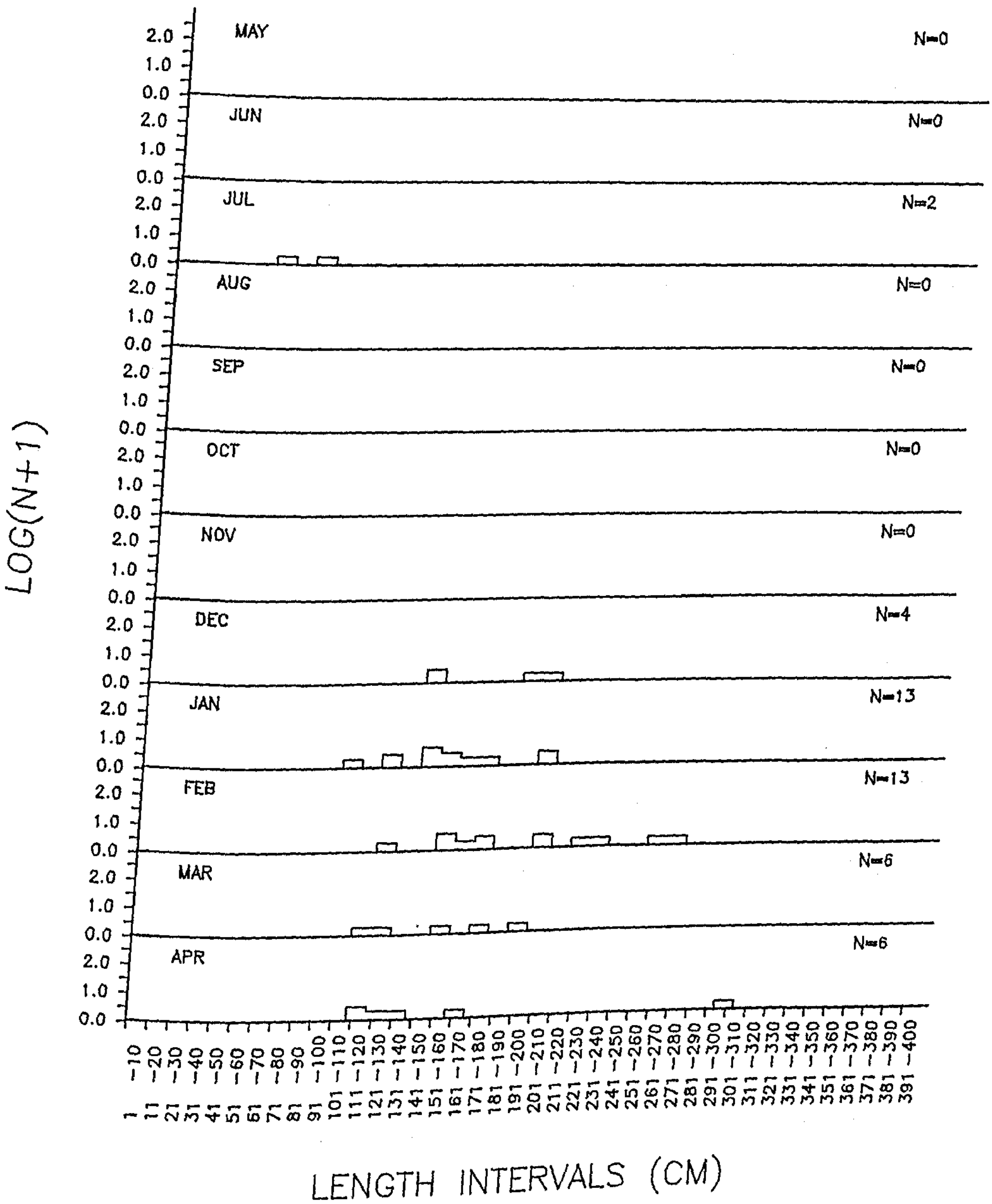
Year-class	Sampling Area	Mean Catch ln(x+1)	Std. Dev.	Geo. Mean	N	Coeff. of Var.	Adj. Coeff. of Var.
1970		1.46	1.596	3.31	54	0.148	
	James	0.70	1.092	1.01	13	0.434	0.302
	York	1.50	1.401	3.48	21	0.204	0.238
	Rappahannock	1.93	1.913	5.89	20	0.222	0.244
1971		0.29	0.464	0.34	60	0.203	
	James	0.07	0.197	0.07	18	0.695	0.371
	York	0.36	0.365	0.43	21	0.218	0.343
	Rappahannock	0.42	0.555	0.52	21	0.288	0.343
1973		0.09	0.343	0.09	90	0.414	
	James	0.00	0.000	0.00	29	0.000	0.000
	York	0.04	0.159	0.04	37	0.697	0.646
	Rappahannock	0.27	0.607	0.31	24	0.459	0.802
1974		0.04	0.240	0.04	101	0.544	
	James	0.00	0.000	0.00	34	0.000	0.000
	York	0.02	0.112	0.02	38	1.002	0.887
	Rappahannock	0.13	0.422	0.14	29	0.608	1.015
1975		0.24	0.564	0.27	102	0.235	
	James	0.02	0.117	0.02	35	1.001	0.402
	York	0.11	0.259	0.12	37	0.379	0.391
	Rappahannock	0.64	0.871	0.90	30	0.247	0.434
1976		0.14	0.377	0.15	75	0.304	
	York	0.22	0.464	0.25	43	0.325	0.401
	Rappahannock	0.04	0.171	0.04	32	0.696	0.465
1977		0.25	0.541	0.28	115	0.200	
	James	0.13	0.374	0.14	45	0.432	0.320
	York	0.48	0.725	0.62	40	0.240	0.340
	Rappahannock	0.13	0.351	0.14	30	0.482	0.393
1978		0.28	0.605	0.32	185	0.158	
	James	0.22	0.502	0.25	65	0.288	0.266
	York	0.36	0.644	0.43	85	0.192	0.233
	Rappahannock	0.20	0.671	0.22	35	0.557	0.363
1979		0.24	0.501	0.27	76	0.237	
	James	0.35	0.617	0.42	33	0.304	0.360
	York	0.21	0.420	0.23	27	0.386	0.398
	Rappahannock	0.07	0.275	0.07	16	1.000	0.517

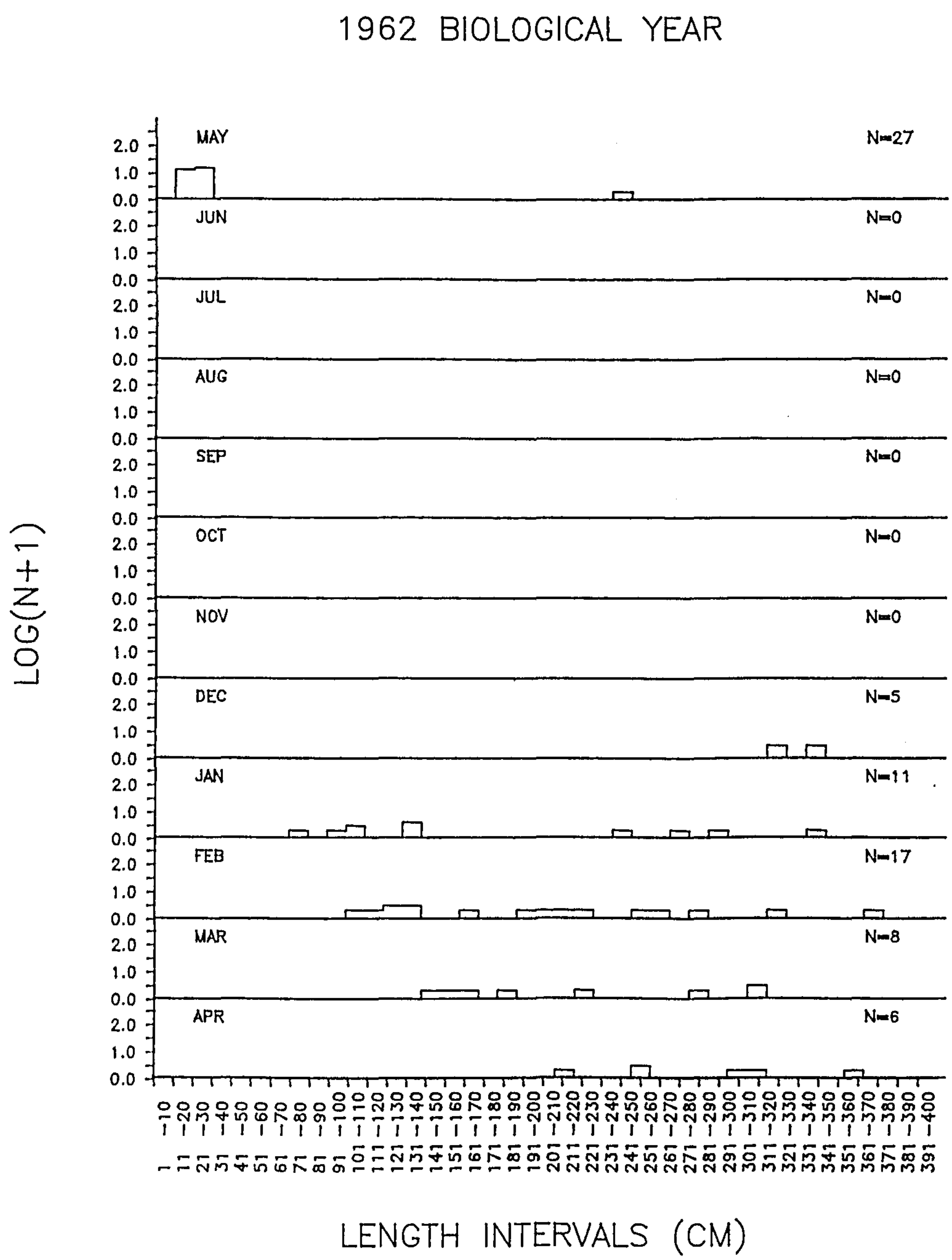
Appendix Table 3. (continued)

Year-class	Sampling Area	Mean Catch ln(x+1)	Std. Dev.	Geo. Mean	N	Coeff. of Var.	Adj. Coeff. of Var.
1980		0.39	0.710	0.48	59	0.236	
	James	0.58	0.815	0.79	30	0.259	0.331
	York	0.31	0.637	0.36	19	0.474	0.416
	Rappahannock	0.00	0.000	0.00	10	0.000	0.000
1981		0.75	0.957	1.12	67	0.157	
	James	0.22	0.708	0.25	20	0.707	0.287
	York	1.29	0.934	2.63	29	0.134	0.238
	Rappahannock	0.45	0.799	0.57	18	0.419	0.302
1982		0.47	0.813	0.60	50	0.244	
	James	0.56	0.878	0.75	6	0.646	0.705
	York	0.44	0.624	0.55	31	0.254	0.310
	Rappahannock	0.50	1.182	0.65	13	0.653	0.479
1983		0.41	0.891	0.51	41	0.341	
	James	0.28	0.837	0.32	13	0.818	0.606
	York	0.38	0.844	0.46	19	0.508	0.501
	Rappahannock	0.64	1.108	0.90	9	0.573	0.728
1984		0.34	0.558	0.40	49	0.232	
	James	0.35	0.502	0.42	16	0.354	0.407
	York	0.27	0.602	0.31	19	0.517	0.373
	Rappahannock	0.43	0.584	0.54	14	0.360	0.435

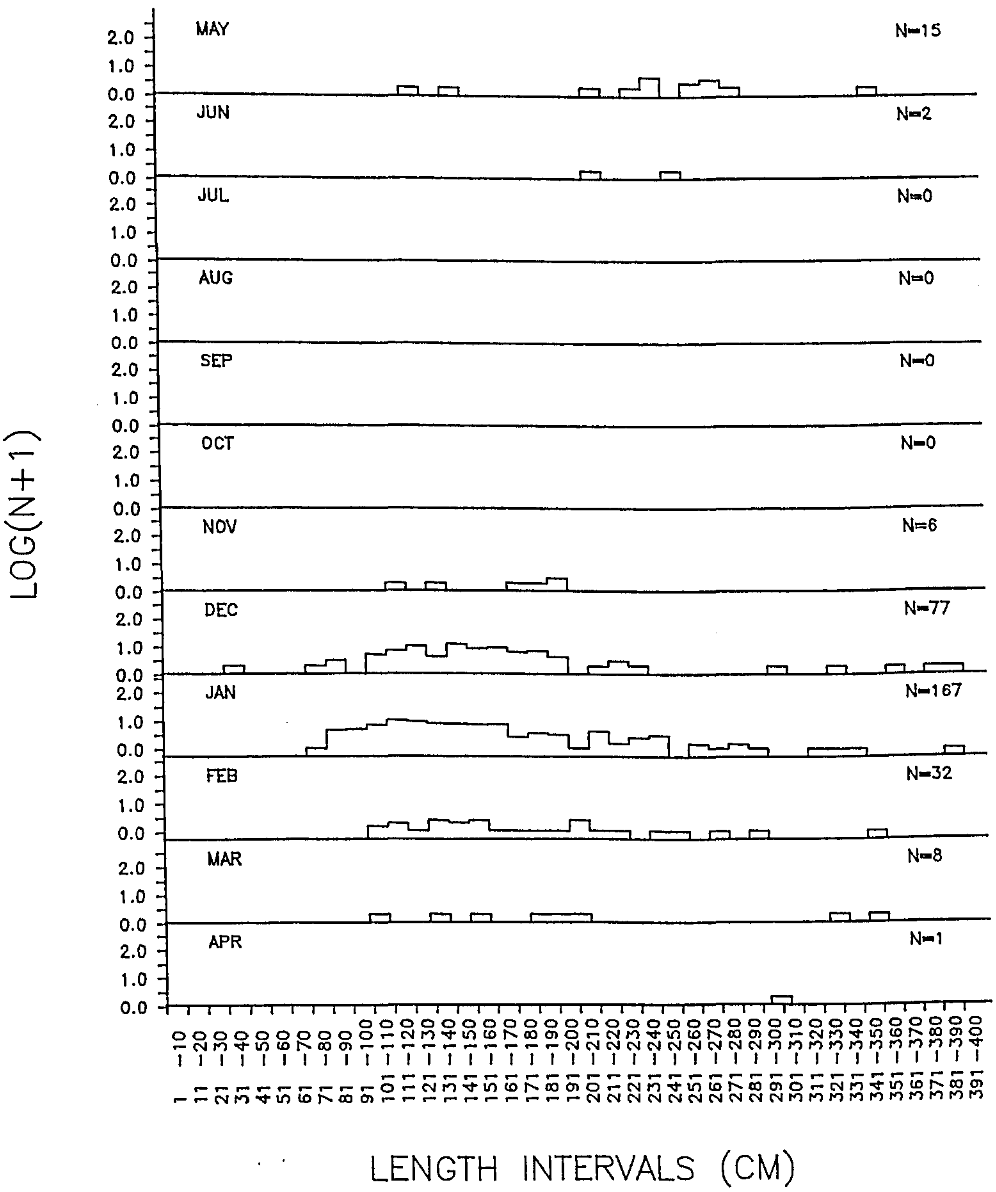
Appendix Figures. Monthly length frequencies of striped bass taken during the VIMS trawl survey by biolgogical year, 1961-1984.

1961 BIOLOGICAL YEAR

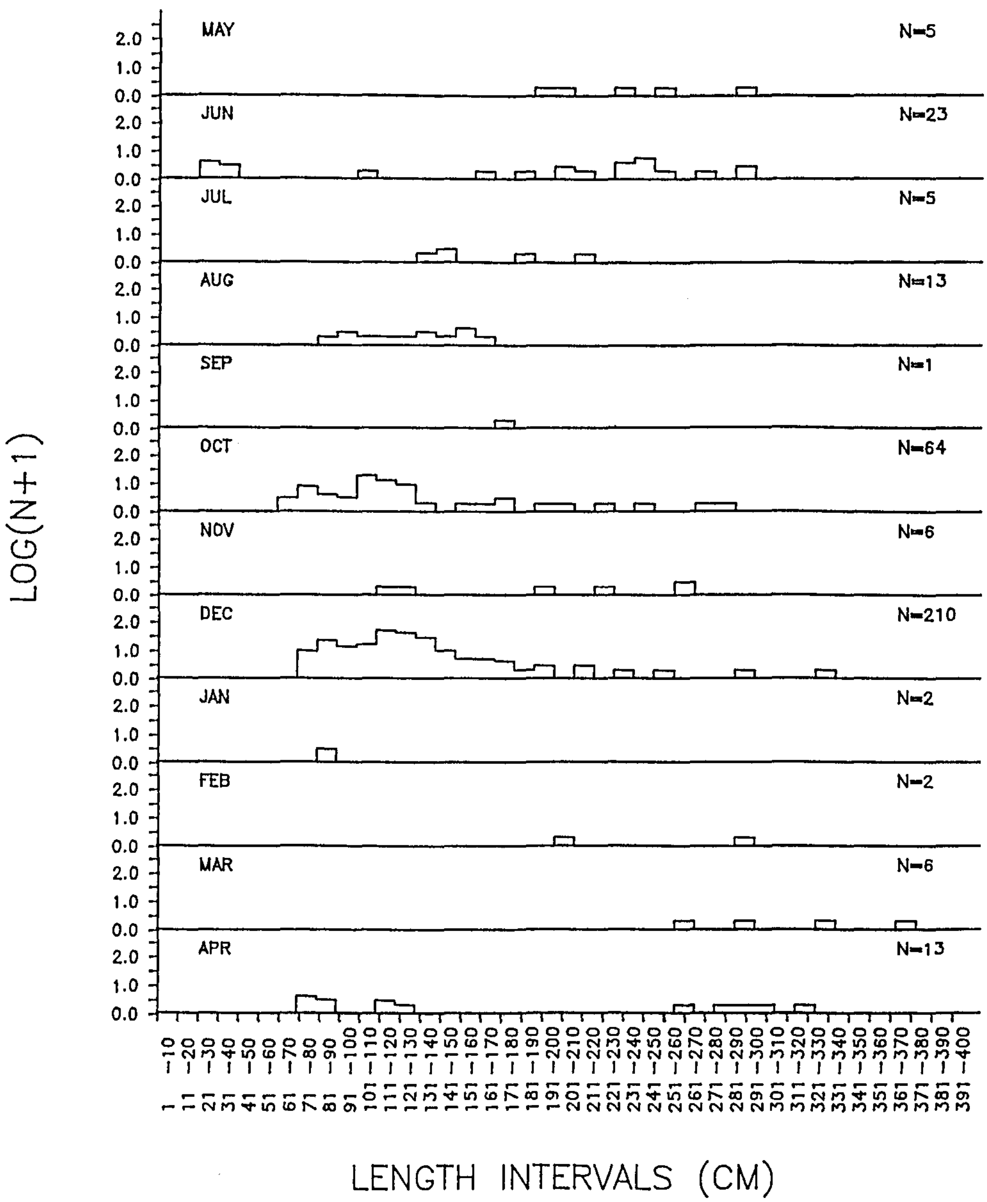



1962 BIOLOGICAL YEAR
MAY N=27
JUN N=0
JUL N=0
AUG N=0
SEP N=0
OCT N=0
NOV N=0
DEC N=5
JAN N=11
FEB N=17
MAR N=8
APR N=6
LOG(N+1)
LENGTH INTERVALS (CM)

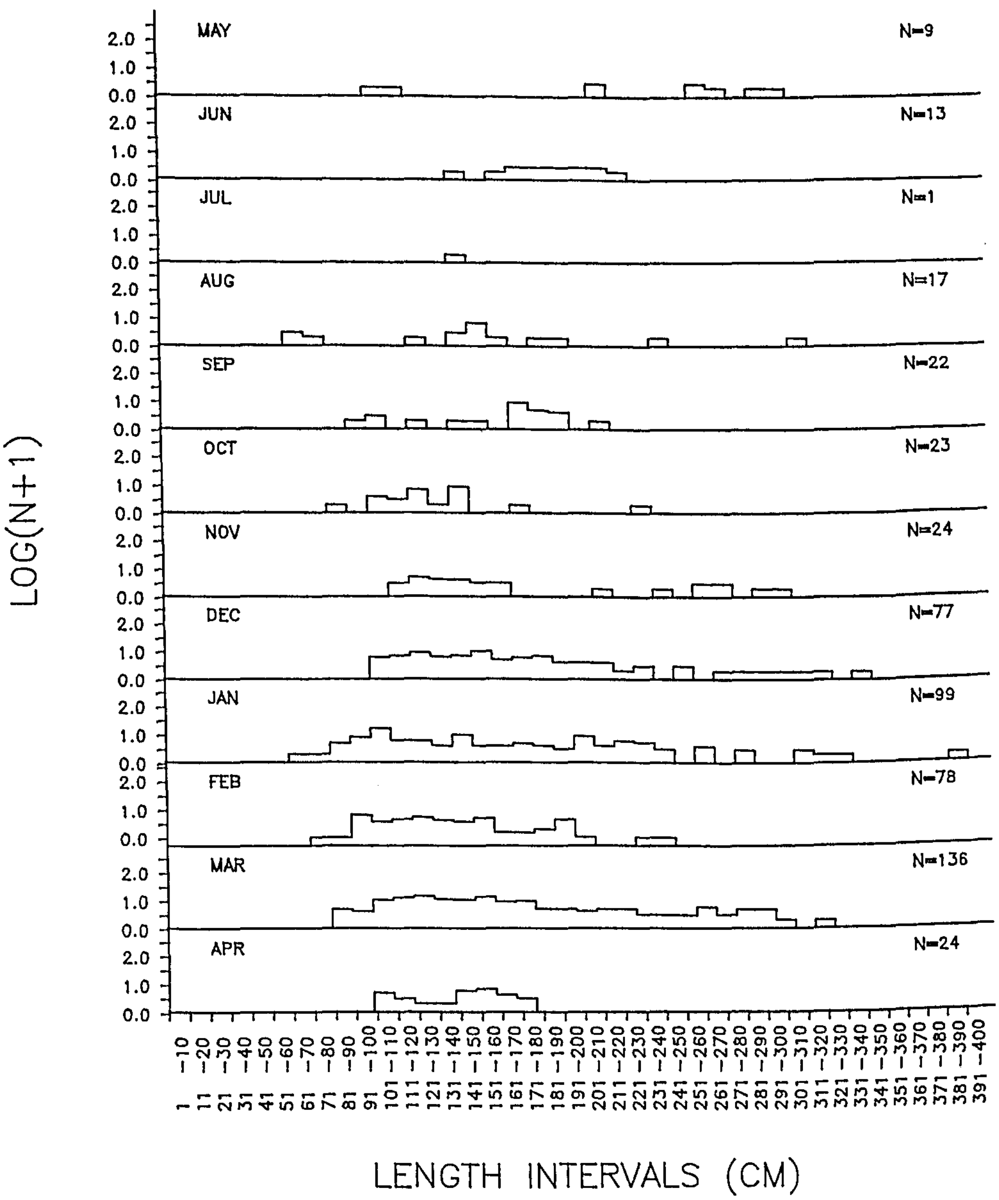
1963 BIOLOGICAL YEAR



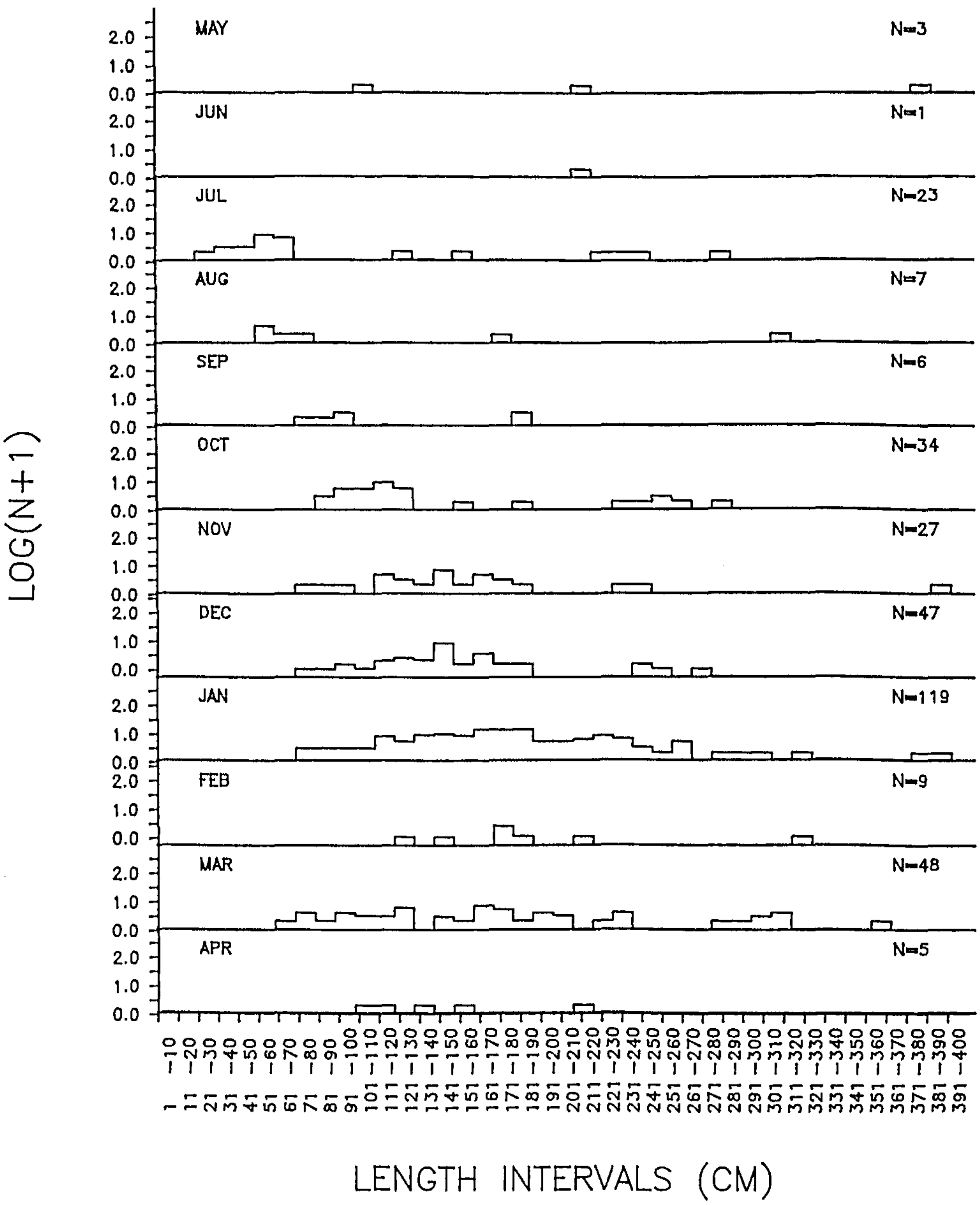
1964 BIOLOGICAL YEAR



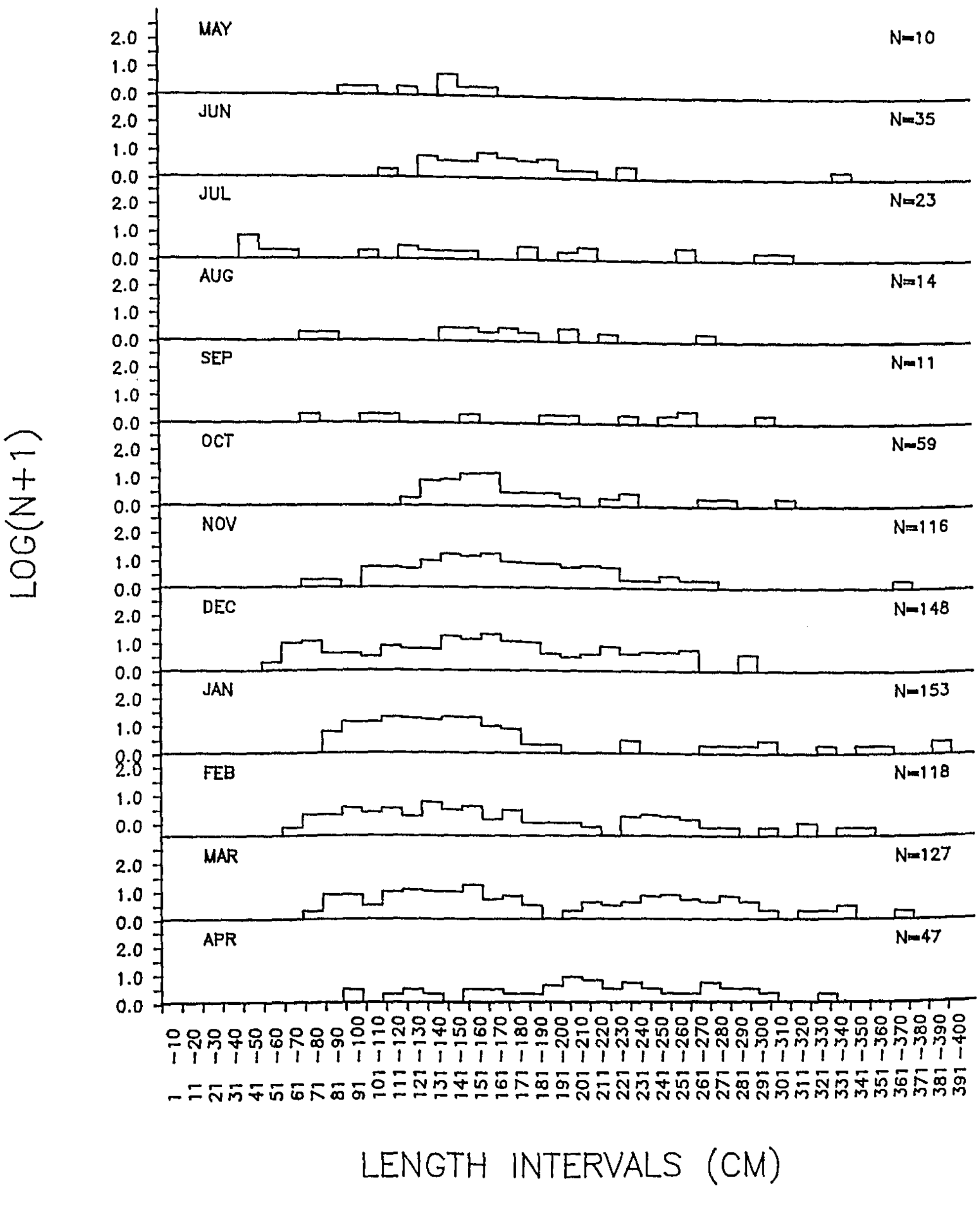
1965 BIOLOGICAL YEAR



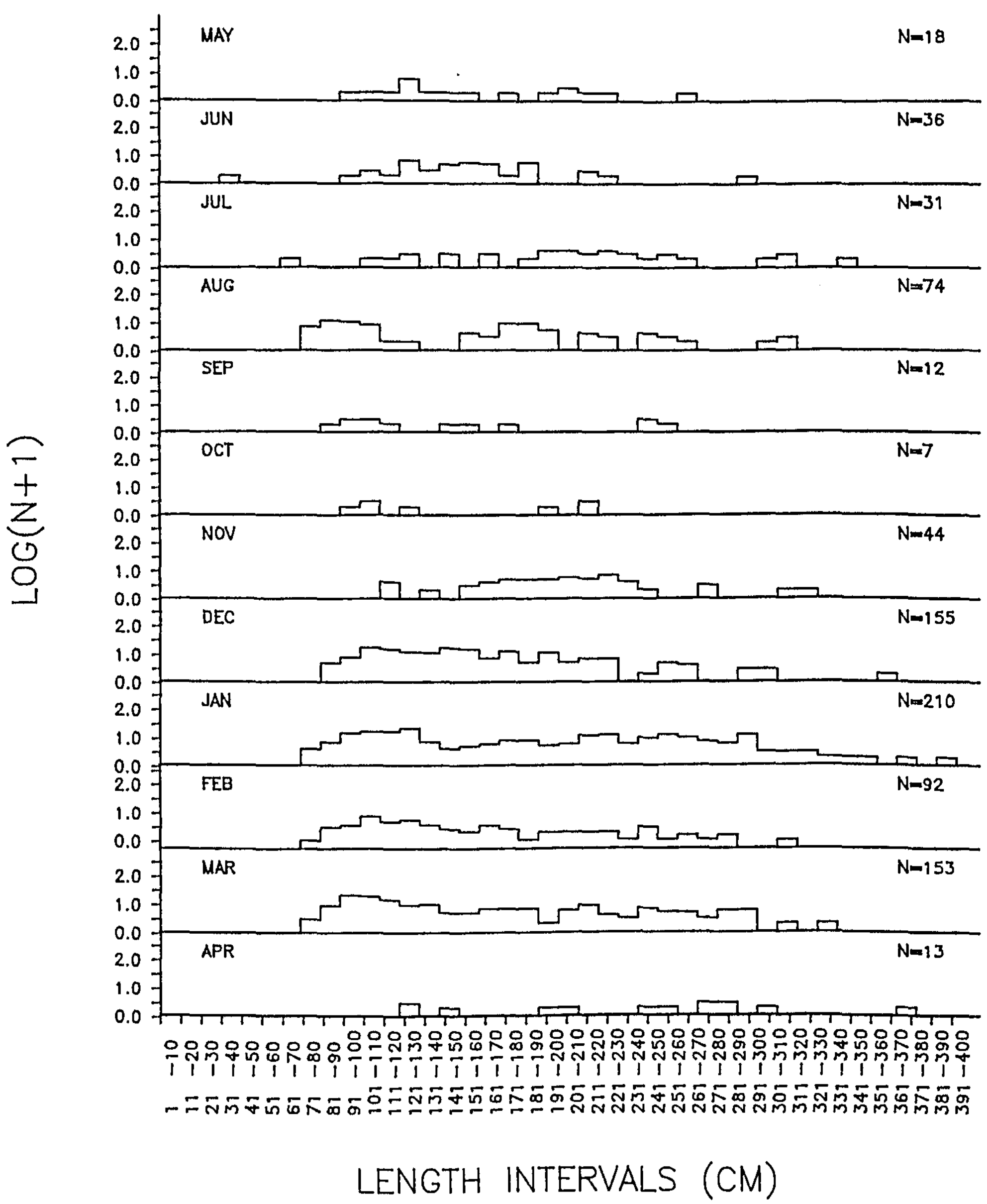
1966 BIOLOGICAL YEAR



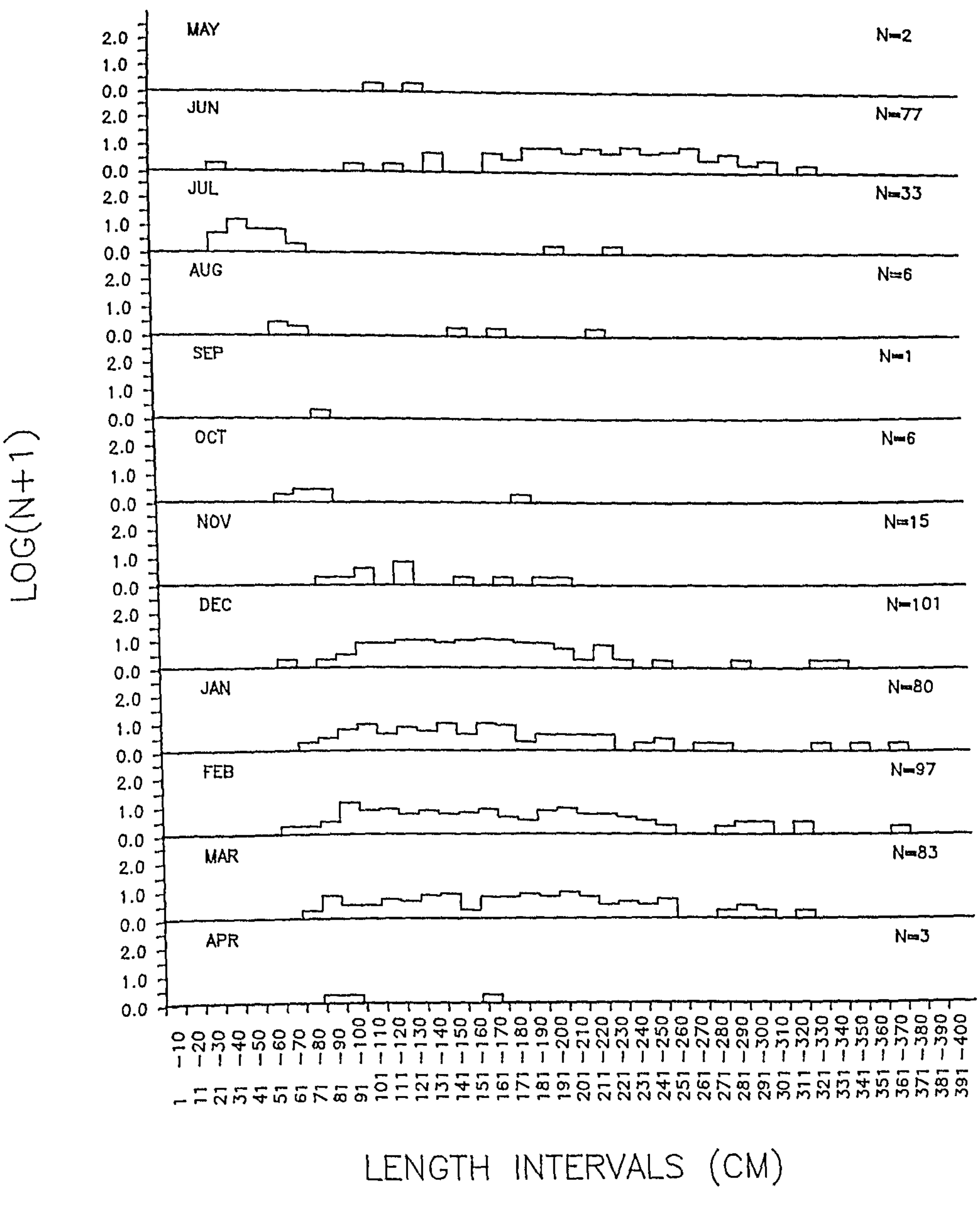
1967 BIOLOGICAL YEAR

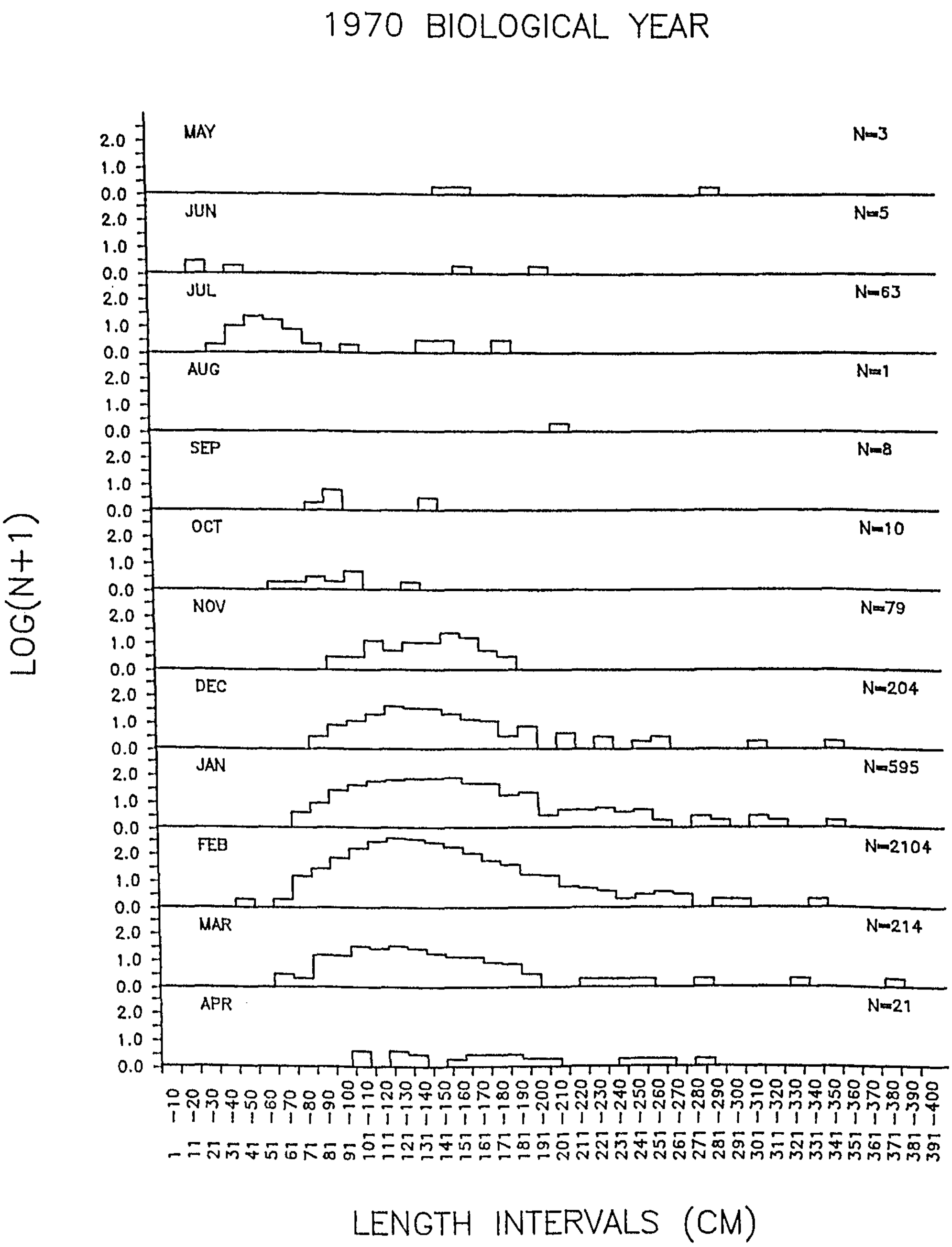


1968 BIOLOGICAL YEAR

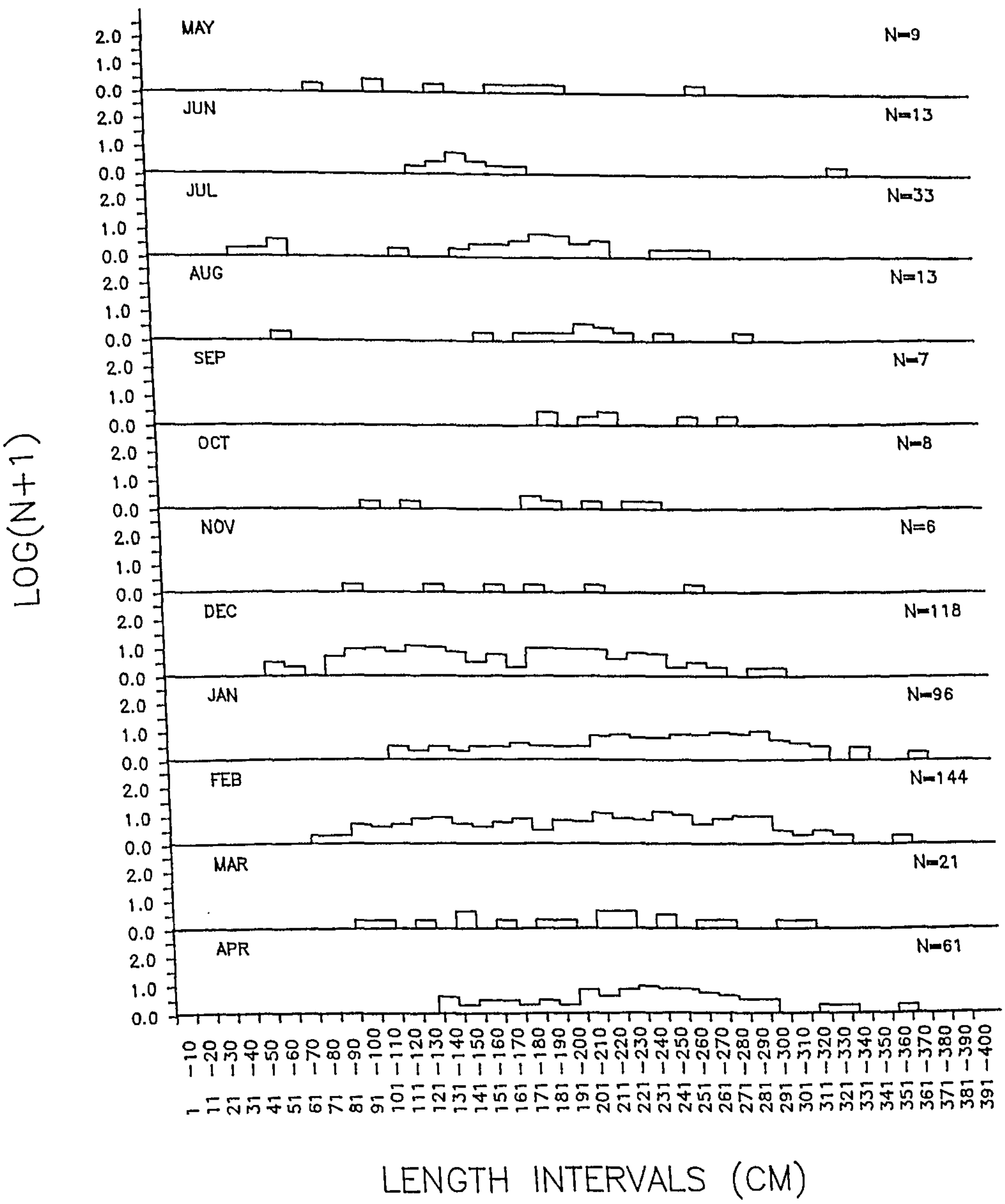


1969 BIOLOGICAL YEAR

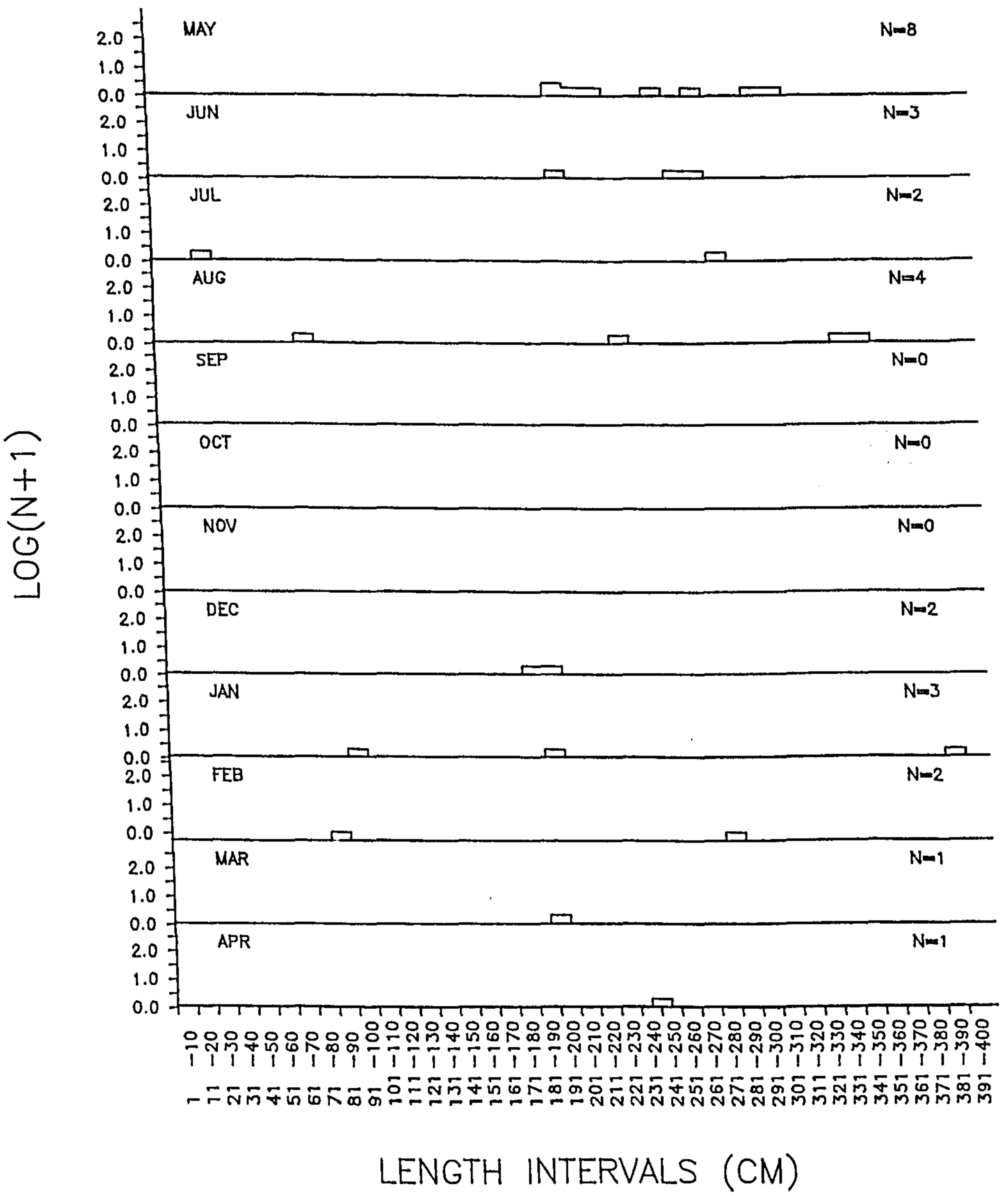



1970 BIOLOGICAL YEAR
LOG(N+1)
MAY N=3
JUN N=5
JUL N=63
AUG N=1
SEP N=8
OCT N=10
NOV N=79
DEC N=204
JAN N=595
FEB N=2104
MAR N=214
APR N=21
LENGTH INTERVALS (CM)

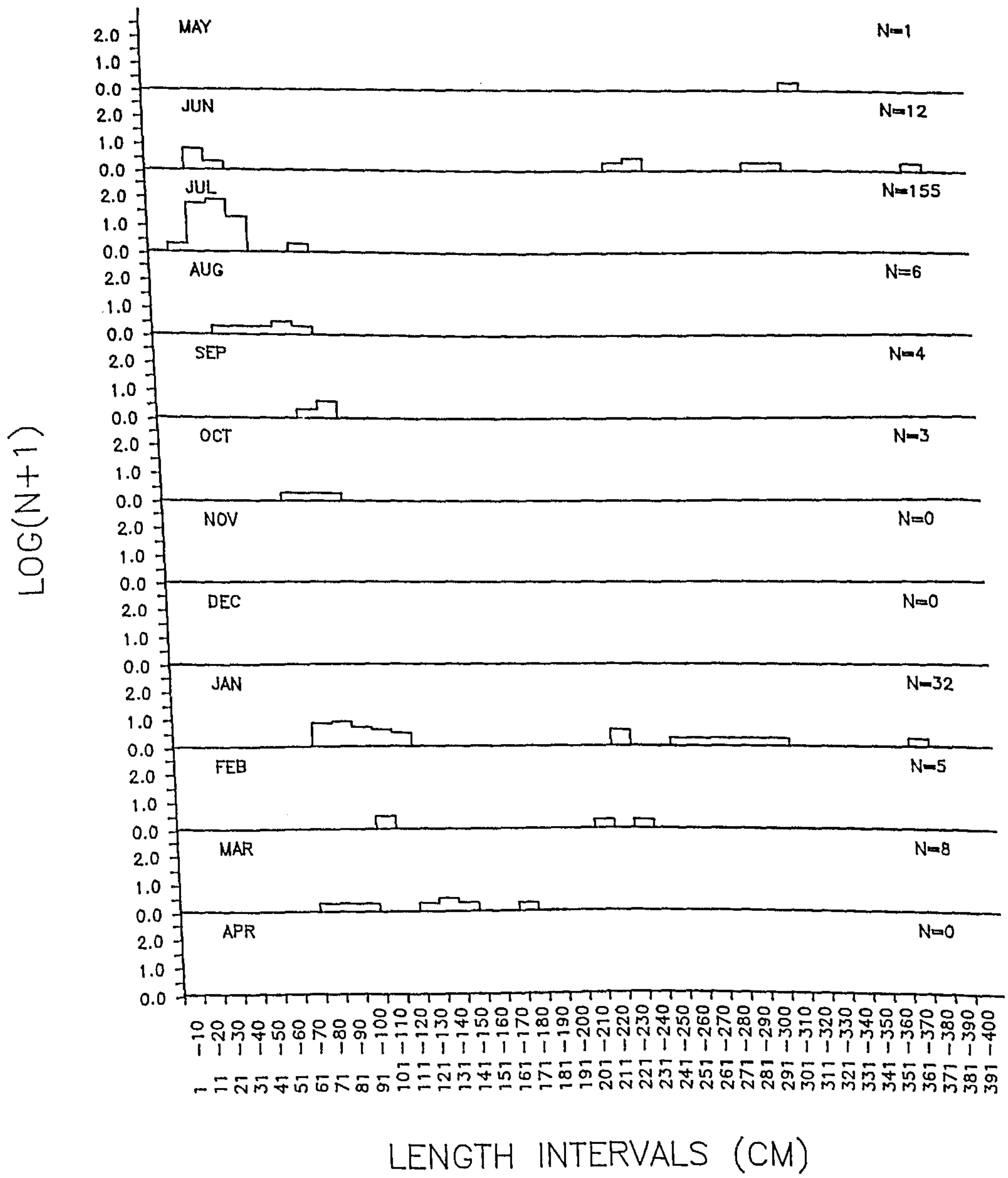
1971 BIOLOGICAL YEAR



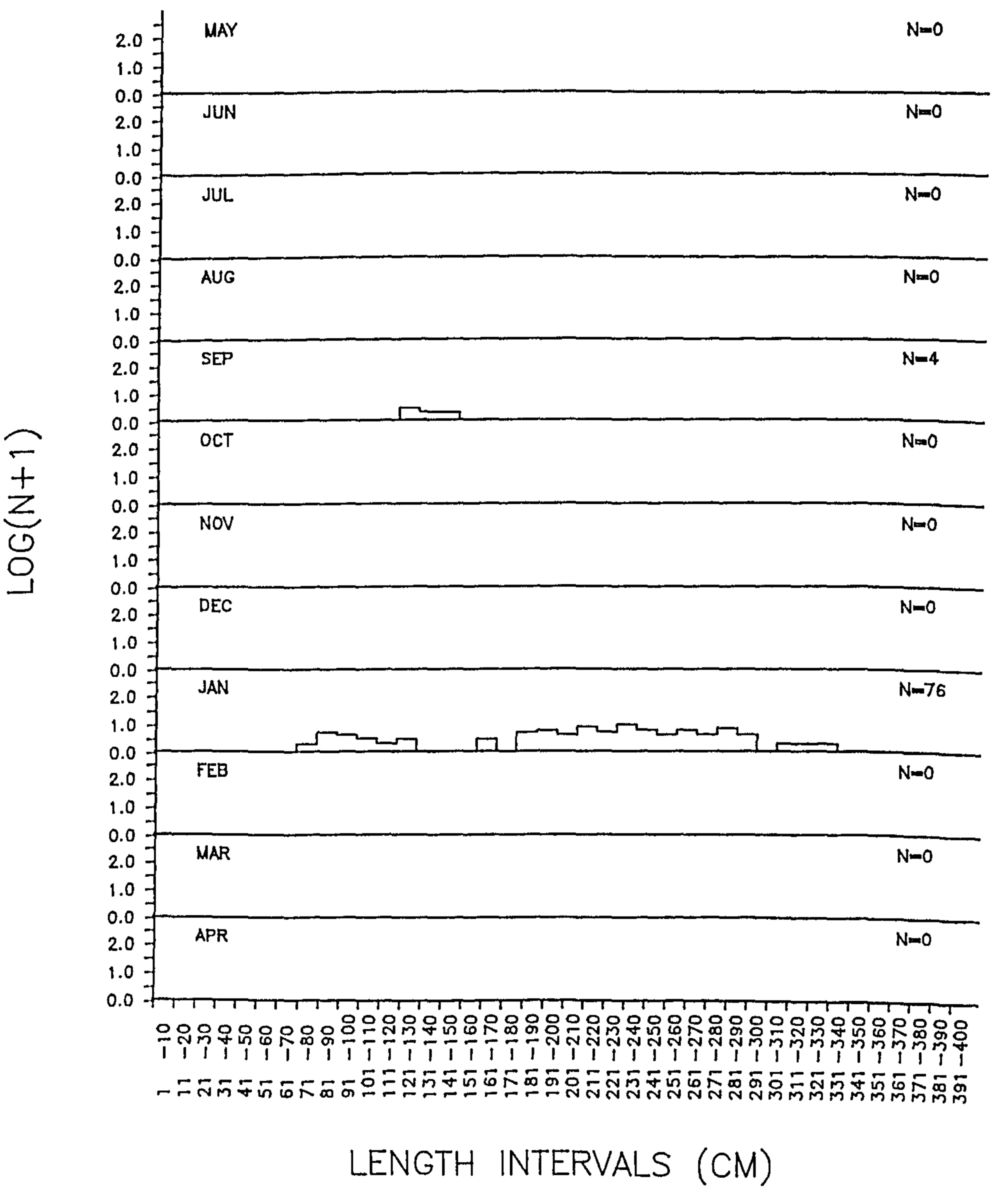
1972 BIOLOGICAL YEAR

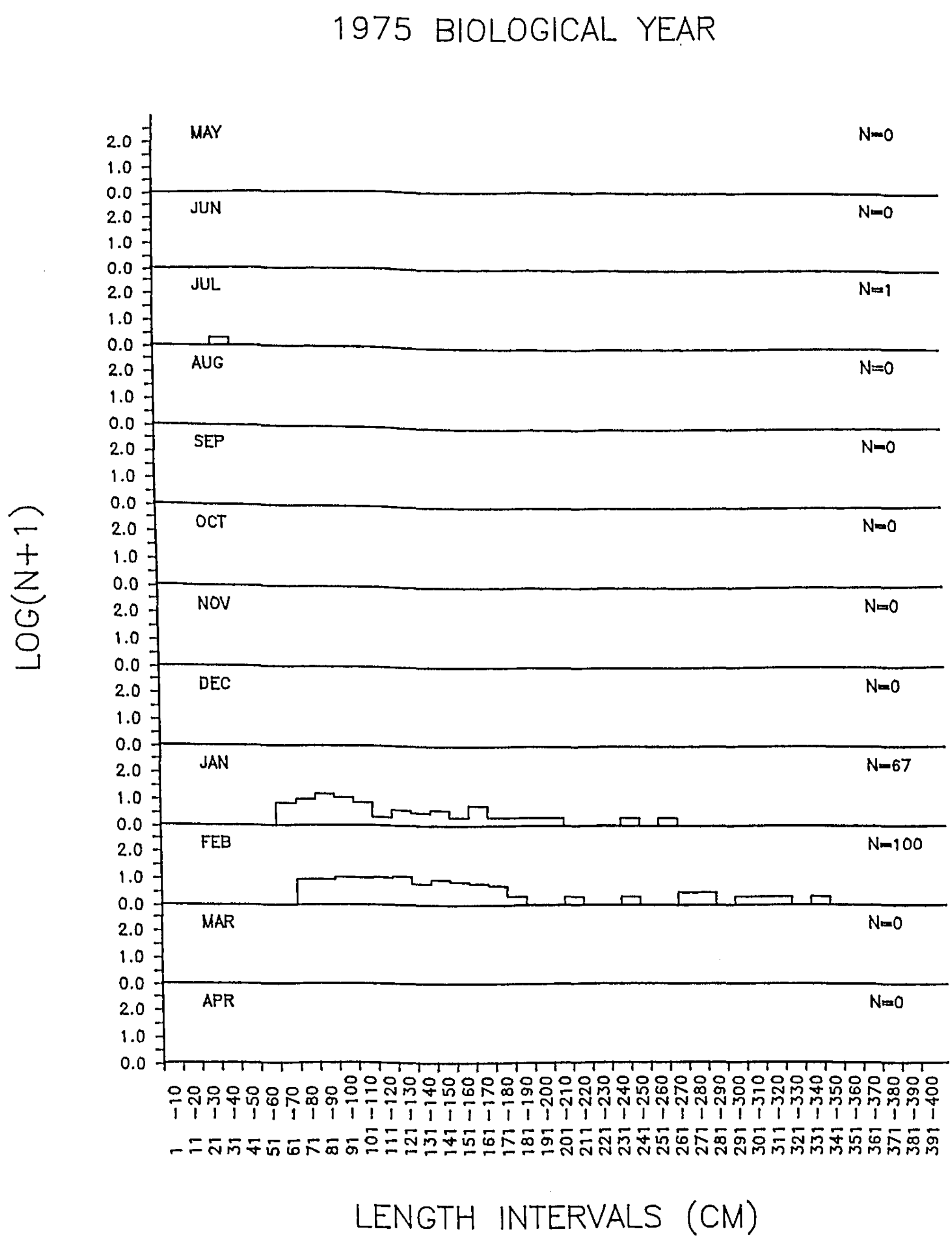


1973 BIOLOGICAL YEAR

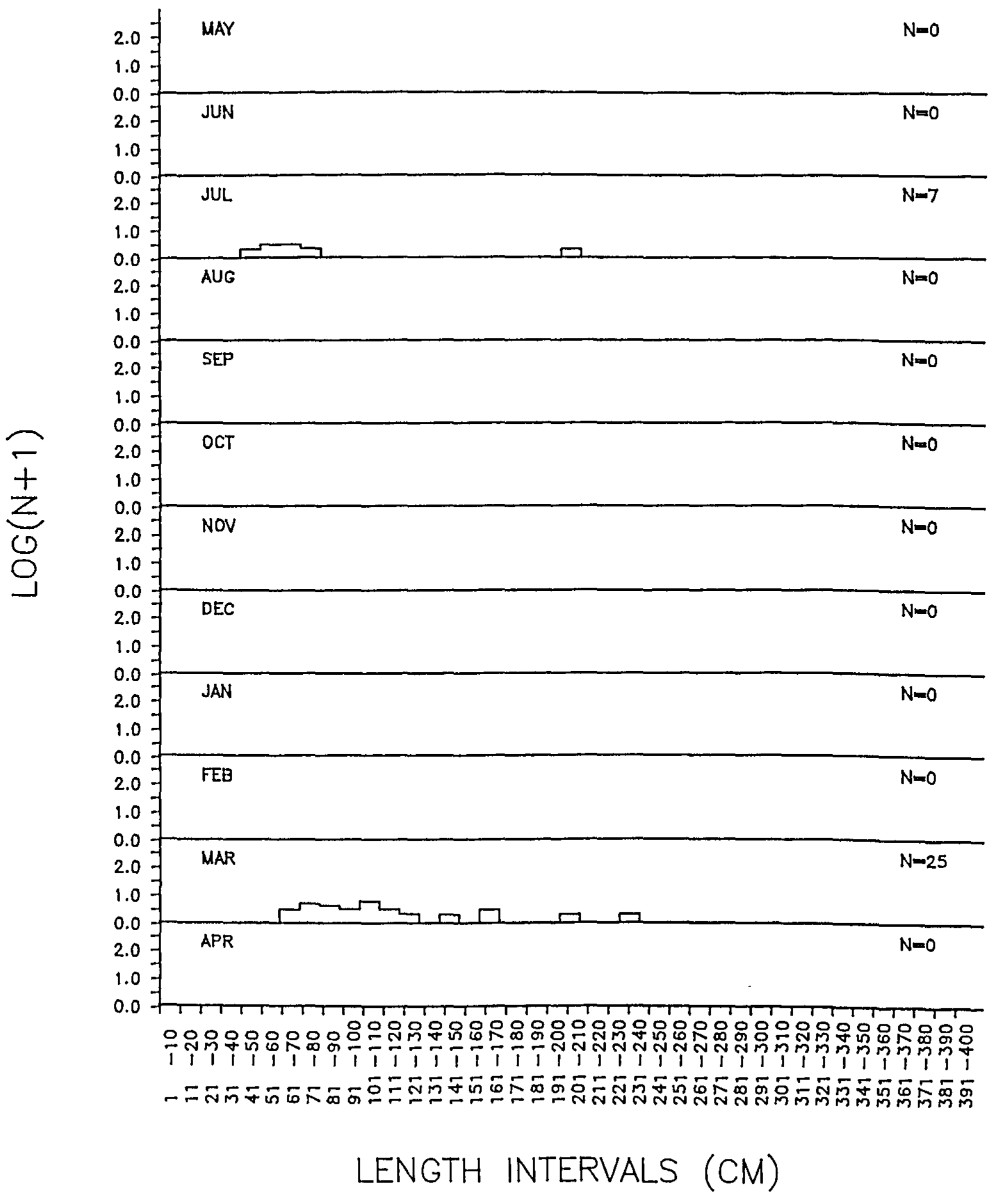


1974 BIOLOGICAL YEAR

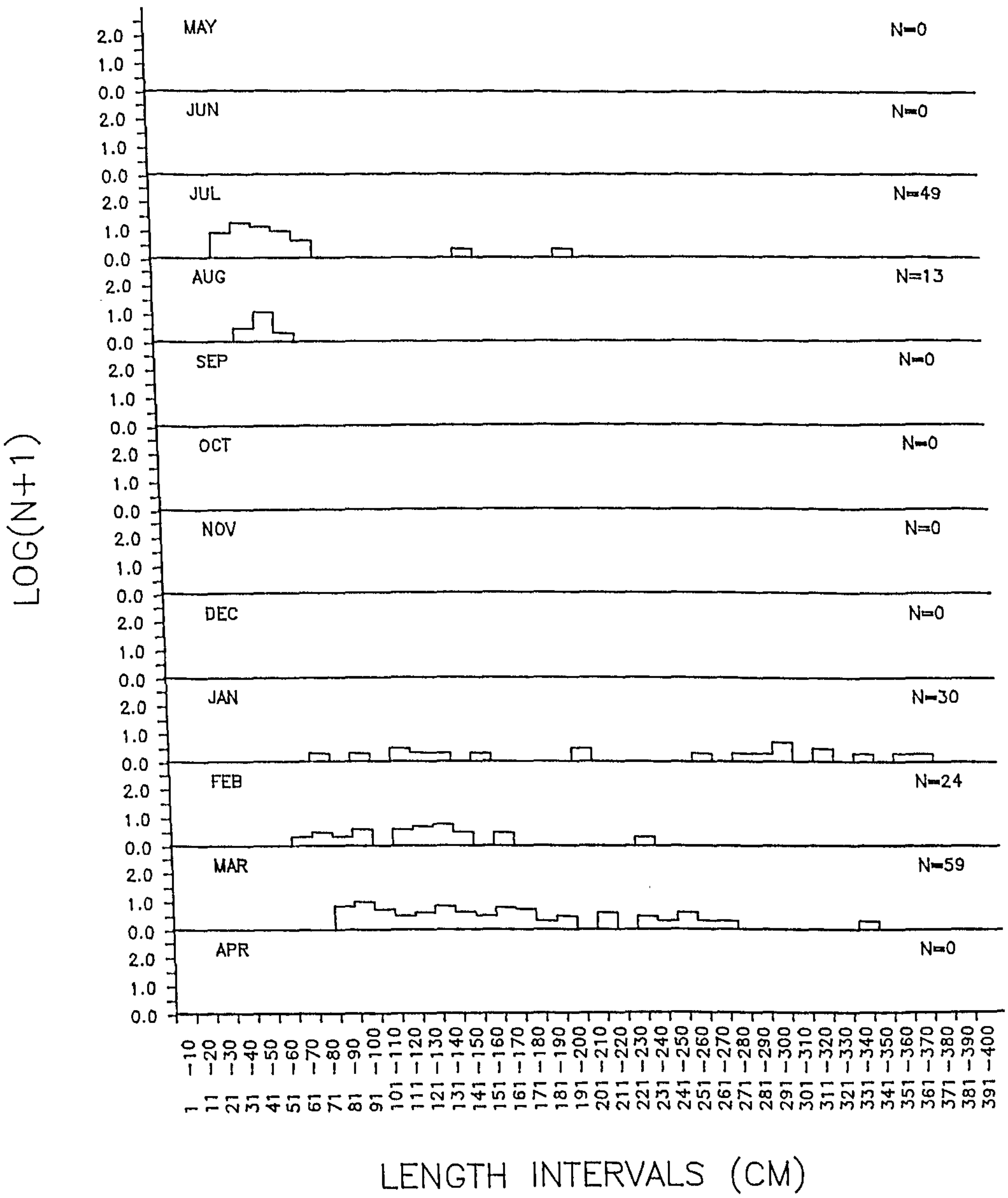


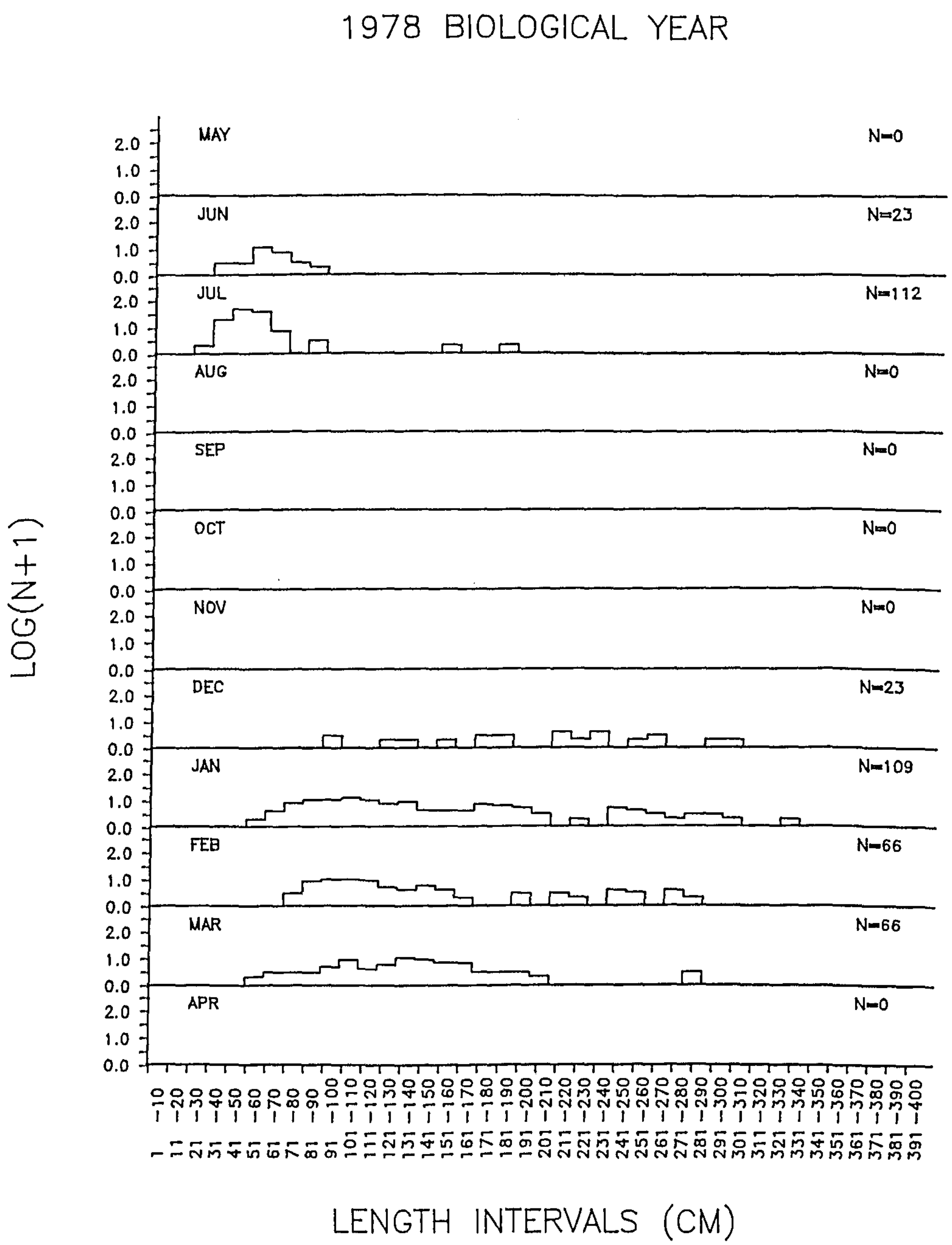

1975 BIOLOGICAL YEAR
LOG(N+1)
MAY N=0
JUN N=0
JUL N=1
AUG N=0
SEP N=0
OCT N=0
NOV N=0
DEC N=0
JAN N=67
FEB N=100
MAR N=0
APR N=0
2.0
1.0
0.0
LENGTH INTERVALS (CM)

1976 BIOLOGICAL YEAR

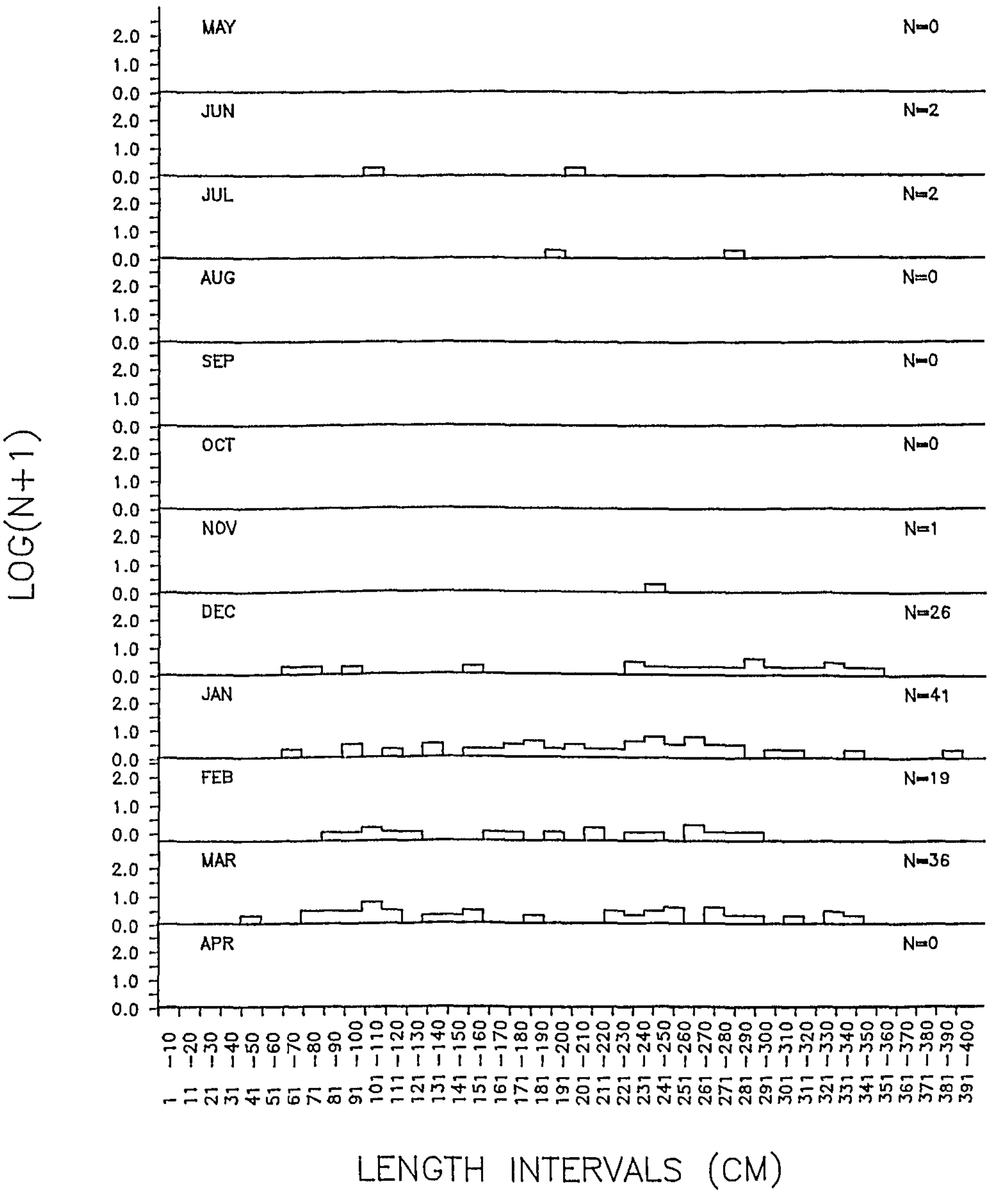


1977 BIOLOGICAL YEAR

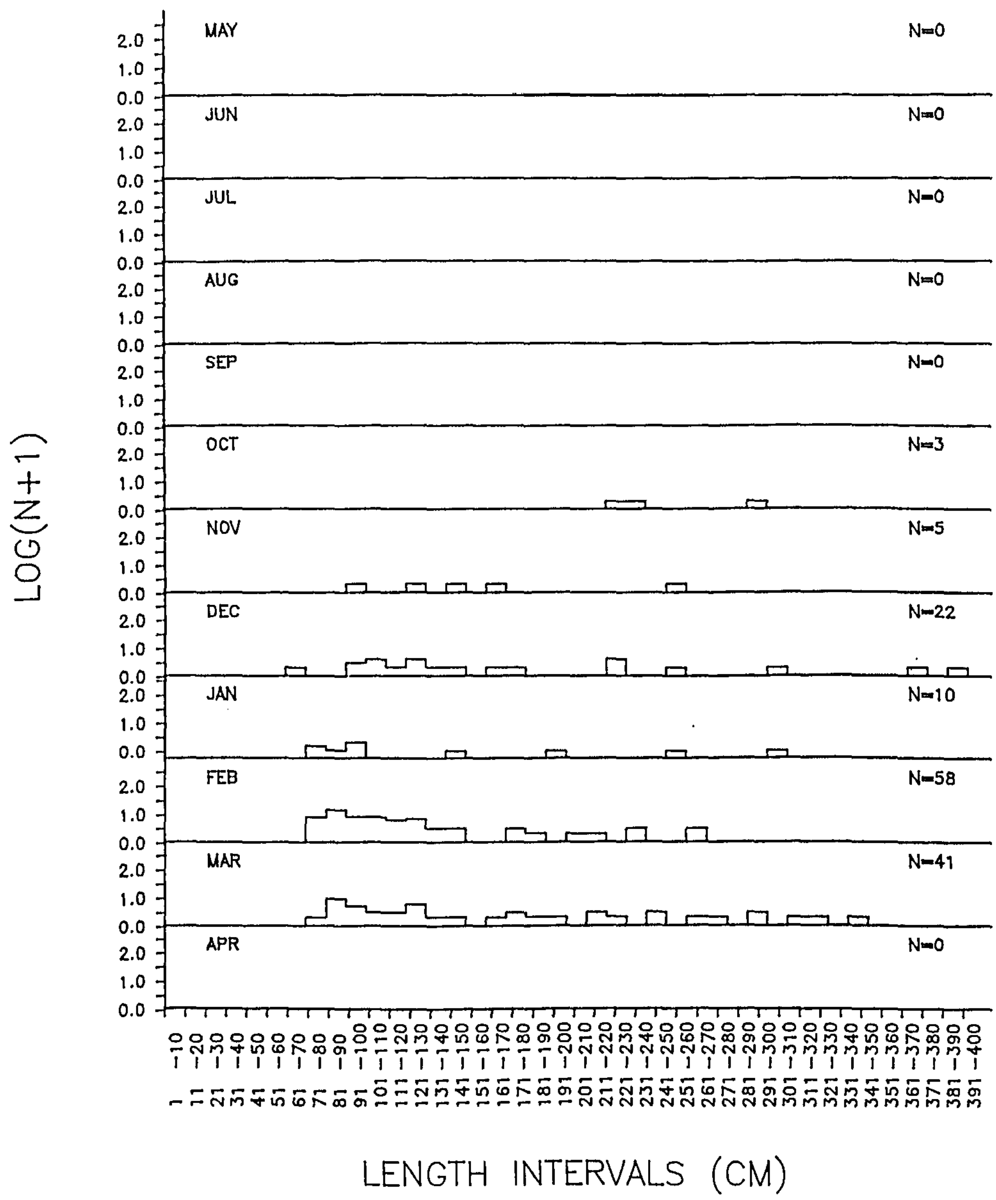



1978 BIOLOGICAL YEAR
MAY N=0
JUN N=23
JUL N=112
AUG N=0
SEP N=0
OCT N=0
NOV N=0
DEC N=23
JAN N=109
FEB N=66
MAR N=66
APR N=0
2.0
1.0
0.0
LOG(N+1)
1 -10
11 -20
21 -30
31 -40
41 -50
51 -60
61 -70
71 -80
81 -90
91 -100
101 -110
111 -120
121 -130
131 -140
141 -150
151 -160
161 -170
171 -180
181 -190
191 -200
201 -210
211 -220
221 -230
231 -240
241 -250
251 -260
261 -270
271 -280
281 -290
291 -300
301 -310
311 -320
321 -330
331 -340
341 -350
351 -360
361 -370
371 -380
381 -390
391 -400
LENGTH INTERVALS (CM)

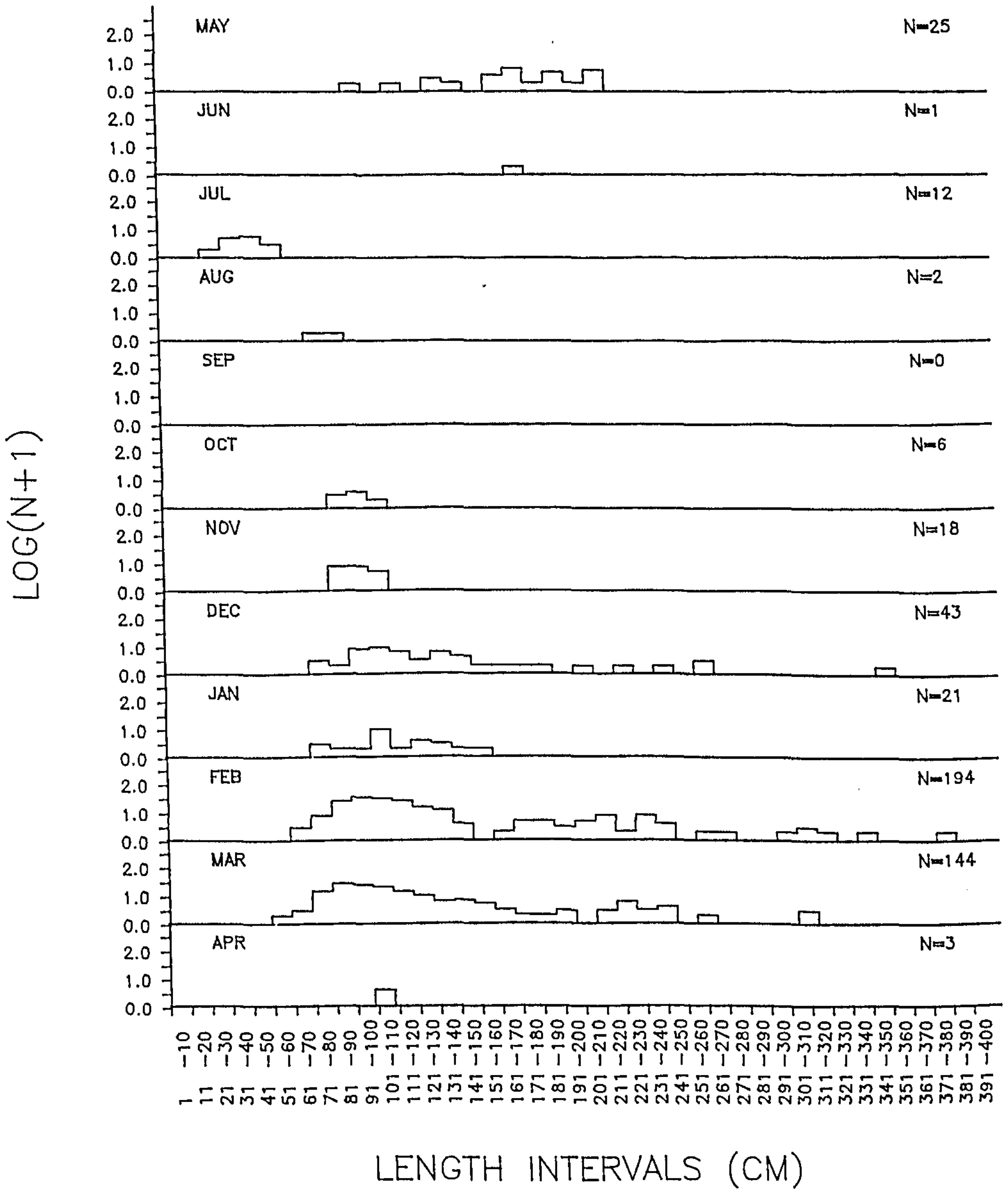
1979 BIOLOGICAL YEAR

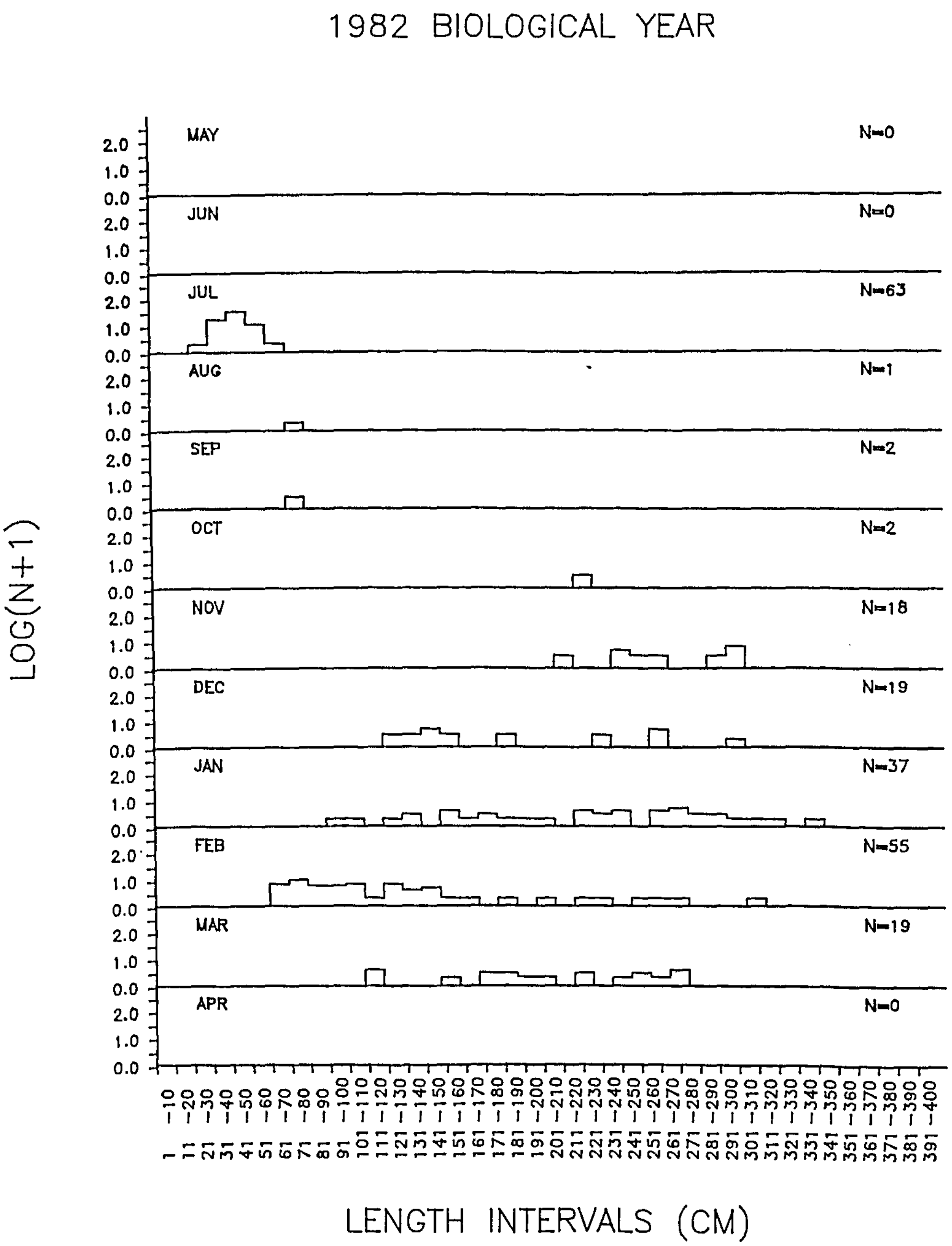


1980 BIOLOGICAL YEAR



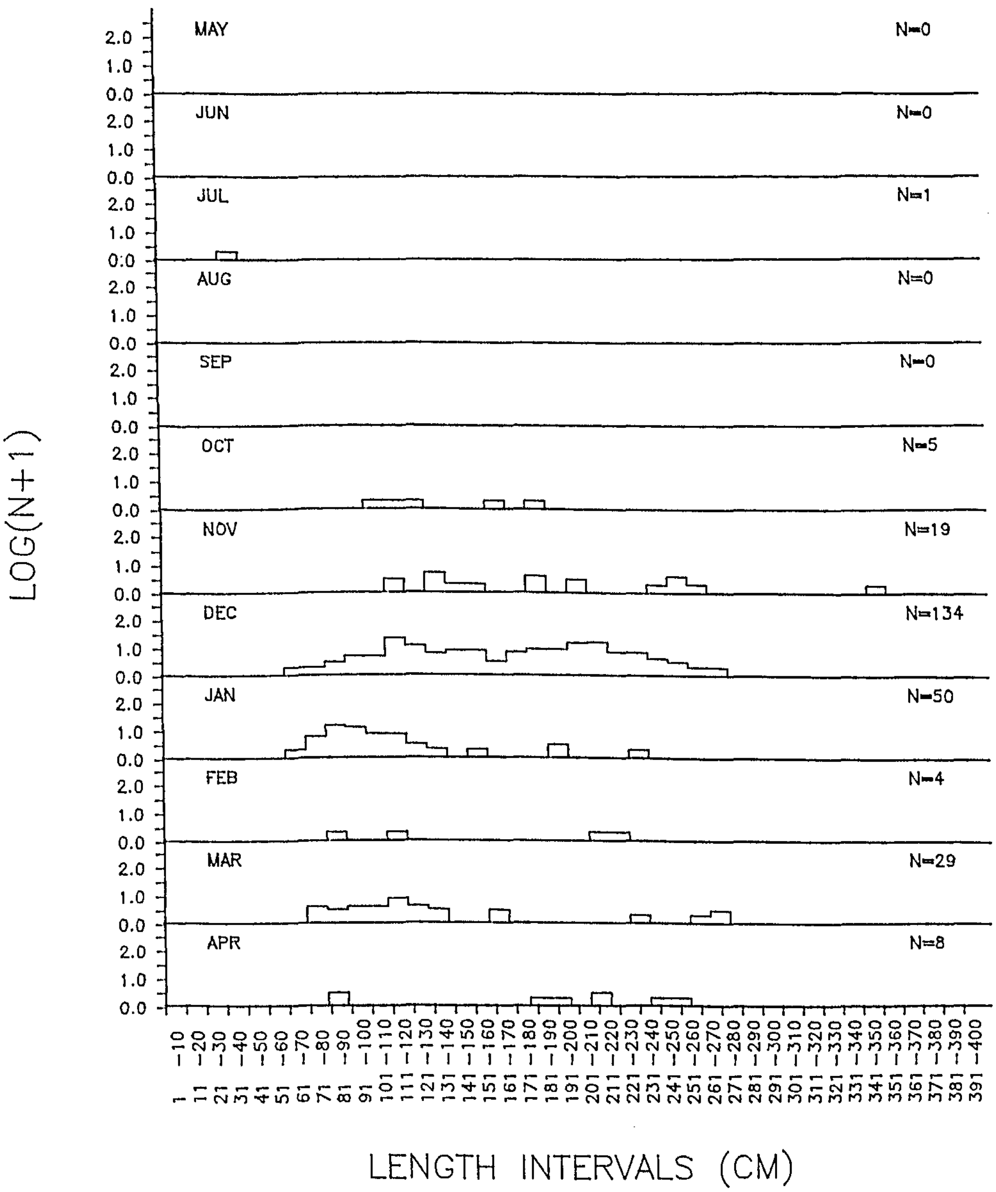
1981 BIOLOGICAL YEAR

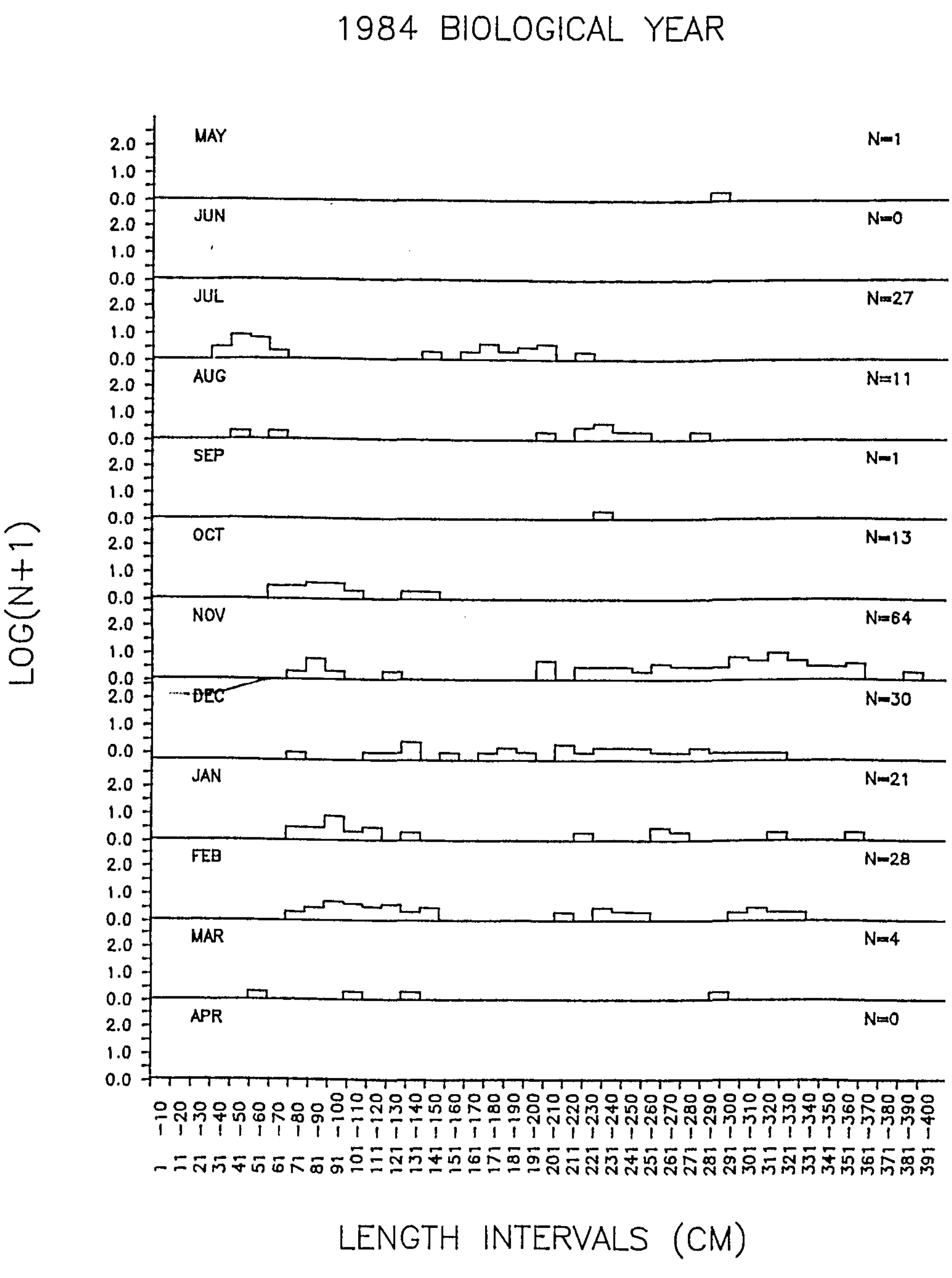




1982 BIOLOGICAL YEAR
LOG(N+1)
MAY N=0
JUN N=0
JUL N=63
AUG N=1
SEP N=2
OCT N=2
NOV N=18
DEC N=19
JAN N=37
FEB N=55
MAR N=19
APR N=0
LENGTH INTERVALS (CM)

1983 BIOLOGICAL YEAR




1984 BIOLOGICAL YEAR
LOG(N+1)
MAY N=1
JUN N=0
JUL N=27
AUG N=11
SEP N=1
OCT N=13
NOV N=64
DEC N=30
JAN N=21
FEB N=28
MAR N=4
APR N=0
2.0
1.0
0.0
LENGTH INTERVALS (CM)